Atlantic Richfield Company

307 East Park Street
Suite 400
Anaconda, Montana 59711
Phone: (406) 563-5211
Fax: (406) 563-8269

October 17, 2002

Mr. Arthur G. Gravenstein, P.E.
Staff Engineer
Bureau of Corrective Actions -- Remediation Branch
Nevada Division of Environmental Protection
333 W. Nye Lane
Carson City, Nevada 89701

Subject: Submittal of Draft Groundwater Conditions Work Plan

Atlantic Richfield Company is pleased to submit the attached Groundwater Conditions Work Plan, pursuant to the Yerington Mine Site Closure Scope of Work. The submittal date reflects the extension provided in your letter dated October 8, 2002.

If you have any questions regarding the attached document, please contact me at 1-406-563-5211 ext. 430.

Sincerely,

Dave McCarthy
Project Manager

DRAFT

GROUNDWATER CONDITIONS WORK PLAN

OCTOBER 14, 2002

PREPARED FOR:

Atlantic Richfield Company
307 EAST PARK STREET, SUITE 400
ANACONDA, MONTANA 59711

PREPARED BY:

BROWN AND CALDWELL
Carson City, Nevada

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SECTION 1.0
INTRODUCTION

Atlantic Richfield Company has prepared this Draft Groundwater Conditions Work Plan (Work Plan) to conduct field investigations that will support an evaluation of ecological and human health risk, and an evaluation of potential impacts to groundwater that may result from past operations and existing conditions at the Yerington Mine Site. Investigations proposed in this Work Plan will be conducted pursuant to the Closure Scope of Work (SOW; Brown and Caldwell, 2002a), and will also support an evaluation of closure alternatives for the site. As stated in the SOW, the Groundwater Conditions Work Plan will:

- "conduct an evaluation of current groundwater management operations and aquifer conditions in the context of site water balance information, including an assessment of the effectiveness of the pumpback well system";
- "include the identification of areas at the mine site, located down-gradient of surface features with the potential to impact groundwater, that have little or no groundwater monitoring data"; and
- "present the locations and preliminary designs for additional monitor well construction".

Additional concepts discussed in this Work Plan include proposed hydropunch investigations and trench testing that were presented in individual Draft Work Plans previously submitted to the Nevada Division of Environmental Protection – Bureau of Corrective Actions (NDEP), the U.S. Bureau of Land Management (BLM), the U.S. Environmental Protection Agency (EPA) and other members of the Yerington Technical Work Group (YTWG).

In addition, components of the previously submitted Draft Wabuska Drain Work Plan (Brown and Caldwell, 2002b) that have relevance to groundwater conditions associated with the Yerington Mine Site are discussed in this Work Plan. A forthcoming Yerington Pit Lake Work Plan, to be submitted later in 2002 pursuant to the SOW, is a second companion Work Plan that has relevance to site groundwater conditions because the pit lake affects groundwater flow at the site. The results of field and laboratory investigations conducted under this Groundwater Conditions Work Plan will be presented in a Data Summary Report.

The remainder of Section 1.0 of this Work Plan describes past mining operations and current site conditions that may affect groundwater conditions at the Yerington Mine Site, the hydrogeologic setting of the mine site including a summary of previous groundwater investigations and related studies, and a description of Data Quality Objectives for this Work Plan. Section 2.0 presents a conceptual hydrogeologic model of the area around the mine site based on available information presented in Section 1.0. Section 3.0 presents the specific components of the Work Plan, based on the Data Quality Objectives and the conceptual hydrogeologic model for the. Section 3.0 also presents a task-specific Job Safety Analysis in the context of the existing comprehensive Site Health and Safety Plan. Section 4.0 lists references cited in this Work Plan.

1.1 Location

The Yerington Mine Site is located west and northwest of the town of Yerington in Lyon County, Nevada (Figure 1). The Walker River flows northerly and northeasterly past the mine site, between the site and the town of Yerington. The river is within a quarter-mile of the southern portion of the site, and the distance between the site and the river increases to the north. Highway 95A is also located between the mine site and the town of Yerington (Figure 1). The Paiute Tribe Indian Reservation is located approximately 2.5 miles north of the site.

The Yerington Mine Site is located in Mason Valley and the Mason Valley hydrographic basin (no. 108) within the Walker River watershed. Agriculture has been the principal economic activity in Mason Valley (principally hay and grain farming, with some beef and dairy cattle ranching). Local onion farming is also present in the area. Surface water diversions from the Walker River and groundwater pumping provide the irrigation water for these agricultural activities.

1.2 Past Mining Operations and Current Conditions

Mining and beneficiation operations for oxide and sulfide copper ores from an open-pit in the southern portion of the mine site were conducted between 1953 and 1978 by Atlantic Richfield's predecessor, the Anaconda Mining Company. Waste rock piles were constructed to the south and to the north of the open pit. Tailings impoundments and process solution evaporation ponds were constructed north of the pit and the mill/precipitation plant areas. The milling process for oxide and sulfide ores varied. Oxide ores were crushed and vat-treated with sulfuric acid. The resulting copper sulfate solution was decanted and the remaining solids were placed in the tailings ponds. The copper sulfate solution was subjected to "iron laundering" in which the copper in solution exchanged with iron, resulting in a copper precipitate. Residual solutions, containing elevated concentrations of iron and sulfate, were conveyed to evaporation ponds at a rate of about 700 gpm (Seitz et. al., 1982).

Sulfide ores were finely crushed, and copper sulfides were recovered using a flotation process with the addition of lime to achieve a neutral pH. Residual solids from the flotation were then placed in the sulfide tailings ponds. The copper concentrates from both milling processes were dried and shipped off-site for smelting. Fine-grained tailings were transported to the ponds as a slurry, and the liquid fraction was recycled for use in further milling. Seepage from the northernmost tailings pond was collected in a peripheral ditch and recycled along with the liquid fraction of the tailings fluid. During mining and milling operations, the tailings deposition areas and associated evaporation ponds and containment ditches were progressively expanded to the north to accommodate the need for increased tailings capacity.

Sietz et. al. (1982) noted that the tailings ponds dried soon after milling operations ceased in June 1978, whereas the solutions in the evaporation ponds from the oxide milling process took longer to dry. The locations of the open pit, waste rock piles, mill processing area, tailings and evaporation ponds are shown in Figure 2.

Arimetco, Inc. acquired the property in 1989, and initiated leaching operations at five lined leach pads located around the site (Figure 2), including the re-handling and leaching of previously deposited waste rock north of the pit. Arimetco also constructed and operated an electro-winning plant with associated solution ponds located south of the former mill area (Figure 2). Some Arimetco leach pads and solution ponds were constructed on the pre-existing oxide tailings areas. Lined evaporation ponds have also been constructed at the site to manage groundwater impacted by mine units and past operations. Since the end of mining and leaching operations by Arimetco in 1996 to the present, the State of Nevada has managed process fluids by re-circulation and evaporation. Beginning in 1986, Atlantic Richfield has managed groundwater by the installation and operation of a pumpback well system located along the northwestern margin of the mine site.

Past mining and ore processing activities at the Yerington Mine have created the current site conditions, with the mine units and process areas shown in Figure 2. These mine units and related surface disturbances can be considered as potential sources of constituents of concern (COCs) to groundwater via leaching of surface materials by meteoric water and infiltration through the unsaturated (vadose) zone.

The existing mine units and process areas include:

Tailings Areas

- Oxide Tailings
- Sulfide Tailings

Waste Rock Areas

- South Waste Rock Area (North)
- North Waste Rock Area

Evaporation and Recycling Ponds

- North, Middle and South Lined Evaporation Ponds
- Finger Evaporation Ponds
- Unlined Evaporation Pond
- Lined Evaporation Pond (South, Middle and North)
- Pumpback Evaporation Pond
- Process Solution Recycling Ponds

Leach Pads

- Phase I Heap Leach Pad
- Phase II Heap Leach Pad
- VLT Heap Leach Pad
- Slot Heap Leach Pad

Process Areas

- Buildings
- Shops
- Fuel Storage Areas
- Ponds and other structures

Arimetco Electrowinning Facilities

- Electro-winning Plant
- Ponds and other structures
- Pipelines, ditches and other conveyances

Ancillary Mine Units

- Landfills
- Sewage Treatment Ponds
- Pipelines, ditches and other conveyances

Companion Work Plans that describe these mine units have been submitted pursuant to the SOW.

1.3 Hydrogeologic Setting

This section describes the general physical and hydrogeologic conditions in the area surrounding the Yerington Mine Site. Information presented in this section includes climate, surface water hydrology, and a description of recharge and discharge components of a preliminary water balance for the area around the site. A preliminary study area outline that includes recharge and discharge areas that affect groundwater flow conditions at the mine site is presented in Figure 3. The extent and boundaries of the preliminary study area is discussed in Section 1.4.

Previous Studies

Information and data from the following studies, also listed as references cited in Section 4.0, have been incorporated into this Work Plan. A brief annotation follows these references:

- Huxel, C.J., Jr., 1969, *Water Resources and Development in Mason Valley, Lyon and Mineral Counties, Nevada, 1948-1965*, Nevada Division of Water Resources Water Resources Bulletin No. 38 prepared in cooperation with the U.S. Geological Survey (this is a comprehensive hydrologic study of the Mason Valley area including water budgets and effects of agriculture on surface and groundwater quality and quantity).
- Seitz, Harold, Van Denburgh, A.S. and La Camera, Richard J., 1982, *Ground Water Quality Downgradient from Copper Ore Milling Wastes at Weed Heights, Lyon County, Nevada*, U.S. Geological Survey Open File Report 80-1217 (this study presents hydrologic and geochemical data on the effects of mining on groundwater quality from a number of monitor wells, most of which are no longer operational).
- Proffett, J.M., Jr., and Dilles, J.H., 1984, *Geologic Map of the Yerington District, Nevada*, Nevada Bureau of Mines and Geology, Map 77.
- Dalton, Dennis, 1999, *Arimetco Yerington Mine and Process Facility Site Assessment of Groundwater Quality*, consultant report prepared for Arimetco, Inc. for submittal to NDEP (interpretations of data presented in this report allege that potential impacts from Arimetco operations could not be distinguished from pre-existing impacts from Anaconda operations).
- Piedmont Engineering, 2001, *Yerington Shallow Aquifer Data Evaluation Report*, consultant prepared for ARCO, March 20, 2001 (interpretations of data presented in this report support specific working hypotheses to be verified.
- Applied Hydrology Associates, 1983, *Evaluation of Water Quality and Solids Leaching Data*, consultant report prepared for Anaconda Minerals Company, May 25, 1983 (interpretations of groundwater data are compared to the Seitz et. al. report; this report includes surface water and solids leaching data in addition to groundwater sampling).
- Applied Hydrology Associates, 2002, *2001 Annual Monitoring and Operation Summary: Pumpback Well System, Yerington Nevada*, consultant report prepared for Atlantic Richfield Company provides groundwater elevation and water quality data for the pumpback and associated monitor wells; also includes pumping rates and time-concentration plots for select constituents; this report helps to interpret the effectiveness of the pumpback well system in limiting down-gradient migration of impacted groundwater).

1.3.1 General Geology

The Yerington Mine site is located on the west side of Mason Valley, a structural basin surrounded by the mountain ranges described above. The area is typical of basin-and-range topography. The mountain blocks are primarily composed of granitic, metamorphic and volcanic rocks with minor amounts of semi-consolidated to unconsolidated alluvial fan deposits. The Singatse Range has been subject to metals mineralization, as evidenced by the large copper porphyry ore deposit at the Yerington Mine.

Proffett and Dilles (1984) published a geologic map of the Yerington District. This map (reproduced as Figure 4) and geologic cross-sections (a portion of two cross-sections, A-A' and C-C', through the mine site are reproduced as Figures 5 and 6, respectively) provide important information on the relationship between bedrock and alluvial deposits at the mine site that may influence groundwater recharge, discharge and flow. Geologic boundary conditions that may affect groundwater flow are shown on the map and cross-sections.

Unconsolidated alluvial deposits derived by erosion of the uplifted mountain block of the Singatse Range and alluvial materials deposited by the Walker River fill the structural basin occupied by Mason Valley in the vicinity of the mine site. These unconsolidated deposits, collectively called the valley-fill deposits by Huxel (1969), comprise four geologic units: younger alluvium (including the lacustrine deposits of Lake Lahontan), younger fan deposits, older alluvium and older fan deposits.

Lake Lahontan lacustrine deposits appear to have been removed and reworked by the Walker River as it meandered back and forth across the valley Huxel (1969). Huxel estimated that Pleistocene Lake Lahontan in Mason Valley persisted for a relatively short time, and was less than 60 feet deep. Table 1, reproduced from Huxel (1969), presents the lithologic and hydrologic characteristics of the alluvial deposits and bedrock units of Mason Valley. These hydrostratigraphic units underlie the mine site and portions of the surrounding study area.

Seitz et. al. (1982) confirmed the geologic setting of the area around the mine site based on existing information and the sub-surface information obtained through the drilling of test (i.e., monitor wells) north of the site by the U.S. Geological Survey in 1978. Alluvial fan deposits along the west margin of the valley and stream- and lake-deposited materials on the valley floor underlie the tailings and evaporation ponds. Seitz et. al. produced the following composite lithologic log from USGS test well 1A and nearby Anaconda well 35, using logs from the original and second wells:

Material [1]	Thickness (feet)	Depth (feet)
Sand, fine	5	5
Sand. fine. Silty	1	6
Sand, silty	13	19
Sand, very fine	7	26
Silt, clayey	3	29
Sand and clay	31	60
Clay, hard	3	63
Sand and clay, interbedded	75	138
Gravel, coarse	14	152
Sand, coarse, with thin layers of clay	224	376
Gravel, coarse, hard	7	383
Sand, coarse, with some thin layers of clay	29	412
Sand and gravel, coarse, firm	8	420
Conglomerate (coarse gravel with matrix of finer-grained sediment; consolidated)	30	450
Consolidated rocks, volcanic	30	500

[1] Sources of data: 0-29 feet, Geological Survey well 1A; 29-420 feet, Anaconda second well 35; 420-500 feet, Anaconda original well 35.

In the area of the evaporation ponds, where recent pumpback well drilling and site investigations have been conducted, the shallow alluvium was described by Applied Hydrology Associates (AHA, 2001) to be composed of the following hydrostratigraphic units:

- Shallow Zone, a dominantly silty sand sequence from the natural ground surface to the top of the Shallow Clay (between 30 to 40 feet below the natural ground surface);
- Shallow Clay, a dominantly clay sequence including the distinctive blue-gray clay to a depth of about 40 feet;
- Intermediate Zone, a dominantly silty sand and interbedded sand and clay sequence that extends from the base of the gray clay to the Deep Clay;
- Deep Clay, the shallowest of several discrete clay layers below the Intermediate Zone that occurs between about 80 and 85 feet; and
- Deep Zone, from the base of the Deep Clay to the bedrock base of the alluvial aquifer.

This succession of hydrostratigraphic units in the alluvial groundwater flow system likely results in horizontal hydraulic conductivity values (generally parallel to bedding) being much greater than vertical conductivity values (perpendicular to bedding), with the resulting anisotropy as great as two orders of magnitude. The area of pumpback and monitor well installation described by Piedmont Engineering is approximately 1,000 feet west of the area of test well 1 and Anaconda well 35 described by Seitz et. al., and tabulated above. Observed lithologic differences between the two areas likely reflect facies changes in the fluvial and lacustrine depositional environments found in the alluvial aquifer at the northern boundary of the mine site.

Atlantic Richfield installed two additional shallow monitor wells in the area north and northwest of the mine site in June 2002. These wells were drilled with a core rig to collect detailed lithologic information from the shallow alluvial aquifer. Core samples generally consisted of a relatively uniform mix of fine-grained sand, silt and clay size fractions with little internal structure (i.e., bedding, laminations, etc.). The exception to the homogeneous character of the core samples occurred immediately above and at the depth where groundwater was intersected in one of the boreholes. At this horizon, fine clay laminations with minor folding or "slump" features were observed. Samples just above the top of the water table in both monitor well boreholes generally contained higher clay contents than those below.

1.3.2 Groundwater Flow Conditions

Seitz et. al. (1982) reported that groundwater recharge to the area of the mine site occurs mostly by percolation from the Walker River and its tributaries, and from irrigation ditches and flood-irrigated fields, as described by Huxel (1969, p. 27). Seitz et. al. depicted generalized groundwater elevation contours north of the mine site for the shallow alluvial aquifer, reproduced in this Work Plan as Figures 7A and 7B (groundwater elevations are presented in feet above the 4,300-foot elevation on both maps). Figure 7A depicts elevations in January 1978, presumably when irrigation effects on flow direction and gradient are minimal. Figure 7B depicts elevations in September 1980, when irrigation effects on flow direction and gradient are significant (i.e., towards the end of the irrigation period). As of September 1980, depths to groundwater ranged from 1 to 9 feet below land surface Seitz et. al. (1982).

Seitz et. al. (1982) attributed a rise from 4.3 to 6.1 feet of groundwater elevations measured in the shallow aquifer between January and September 1978 to the "cessation of industrial-well pumping when mining and milling terminated in mid-year" or to "the irrigation of alfalfa fields in the study area with river water during the spring and summer of 1978". By September 1980, Seitz et. al. noted that the water table had risen even more and that the configuration of the water table shifted. This change in the direction of shallow groundwater movement from north to northwest is reflected in Figures 7A and 7B.

Seitz et. al. (1982) concluded that some of this change was due to irrigation effects at the time of the 1980 measurements, while most of the change resulted from the cessation of industrial (i.e., mining-related) pumping. The relative importance of the industrial pumping to the observed change is not consistent with Huxel's conclusion that the mine-related pumping had little or no observable affect on the groundwater flow in the shallow alluvial aquifer, and with the conceptual model presented in Section 2.0 (i.e., it is more likely that irrigation recharge would have a more direct and immediate effect on water levels in the shallow aquifer than effects from deeper pumping). Seitz et. al., (1982) noted that the elevated water table was evident by the "inundation of low-lying features such as borrow pits and the low-gradient drainage ditches, particularly the Wabuska Drain".

In addition to the empirical observations of hydrogeologic conditions described above for the area immediately north of the mine site, Seitz et. al. approximated the down-gradient (generally northward) velocity of groundwater flow through the study area by using estimates of hydraulic properties including transmissivity, effective porosity, and water-table gradient. This analysis incorporated a correlation of aquifer transmissivity to specific capacity, well drilling data for the deeper Anaconda wells, and standard assumptions about well efficiencies (e.g., fully efficient) and aquifer characteristics (e.g., homogeneity and isotropy) to calculate hydraulic properties of the shallow aquifer.

Using these properties, and the following equation, Seitz et. al. (1982) estimated the average velocity of groundwater flow in the alluvium north of the mine:

$$v = T(dh/dl)/bq$$

Seitz et. al assumed an average transmissivity value (T) of 7,000 feet squared per day, an average effective porosity of 0.15 (q) for the uppermost 500 feet (b) of saturated sedimentary deposits, and an average water-table gradient of 0.002 (dh/dl). Based on these hydraulic properties, the average groundwater velocity (v) was estimated at 0.2 foot per day (about 75 feet per year). This estimate of velocity was, at best, only an order-of-magnitude value because it was based on very limited aquifer data (Seitz et. al., 1982).

Available well construction information from the monitor wells installed by the U.S. Geological Survey and described by Seitz et. al. (1982) are provided in Appendix A. Appendix A also includes available well construction information from all site monitor wells and pumpback system wells installed through June 2002. Figure 8A shows the locations of all groundwater monitoring locations within the study area, including the following types of wells (or borings):

- Site monitor and pumpback wells;
- Production and dewatering wells;
- Hydropunch boring locations;
- Domestic wells that have been monitored for water quality; and
- Wells that have been abandoned or lost.

Figure 8B also shows the locations of mine site monitor wells, including those monitored in June 2002. Figure 8C shows the locations of domestic wells, including those monitored in June 2002. Both figures show the location of the Phipps domestic well, which has been included in recent groundwater monitoring reports (e.g., Piedmont, 2001 and AHA, 2002) along with other site monitor wells. Groundwater elevation and water quality data from the June 2002 monitoring event are discussed below (water quality data in Section 1.3.8).

Figure 9 reproduces the potentiometric surface contours in August/September 1999 for the shallow aquifer from Piedmont Engineering Inc. (2001). This map depicts groundwater elevation information from the available monitor wells on the north side of the mine site and from hydropunch data collected in 1999, and presents groundwater flow directions perpendicular to the contours. Wells used to compile the contour map include pumpback wells and monitor wells screened in the shallow alluvial aquifer (nominally, the upper 60 to 100 feet of saturated thickness). The method for inclusion of the pumpback wells may be the cause of the relatively steep gradients shown in Figure 9 for the northern portion of the mine site. The contouring method appears to have treated the pumping water levels in the 11 pumpback wells in a similar fashion as the groundwater elevations in monitor wells and hydropunch locations. Groundwater elevations measured in pumping wells may be lower than in the adjacent aquifer due to to well inefficiency.

The complexity of the contours and flow paths in the area of the mine shown in Figure 9 may result from the use of groundwater elevation data from wells screened, and hydropunch completions, in hydraulically distinct portions of the aquifer and, more certainly, by the effects of the pumpback well system located along the northwestern margin of the mine site (i.e., kriged groundwater elevation contours can misinterpret the shape of a drawdown cone around a pumping well). During the August/September 1999 period when these water elevation measurements were made, the pumping rates for the PW wells were:

WELL	AVERAGE PUMPING RATE (gpm) August/September 1999
PW-2	12.39
PW-3	11.34
PW-4	2.87
PW-5	2.43
PW-6	3.93
PW-7	3.12
PW-8	3.90
PW-9	4.08
PW-10	2.63
PW-11	5.97

No records were available for PW-1 during this period. The total of the pumpback wells listed above is 52.66 gpm. Investigations proposed in this Work Plan will evaluate the area of influence (i.e., cone-of-depression) of the pumpback wells and their effect on groundwater flow in this area of the mine site. Some of the older pumpback wells (PW-2 and PW-4) and all of the newer pumpback wells (PW-6 through PW-11) had pumping water levels between 10 and 20 feet below the surrounding potentiometric surface.

Based on water elevations measured in nearby monitor wells, pumpback wells PW-8 through PW-11 appear to influence the shallow alluvial aquifer, including monitor well W5BB, located northwest of PW-11. PW-7 was not pumping at the time of the measurements (Piedmont, 2001), resulting in a water level in this pumpback well that might more clearly reflect the actual potentiometric surface at this location.

Figure 10A presents a groundwater elevation contour map for the same area based on water level measurements for site monitor wells in June 2002., Groundwater elevations range from 4,340 feet amsl on the east side of the map to approximately 4,332 feet amsl on the west side of Figure 10A. These elevations appear to represent an east-to-west gradient, and a general decline of the water table since August/September 1999 in this area of about five to eight feet. Figure 10B presents a groundwater elevation contour map for an expanded area of the mine site.

The larger decline of about eight feet is located at the base of the alluvial fan (west side of map in Figure 10A), possibly suggesting the effect of generally lower precipitation in the Singatse Range over the last three years. The decline of approximately five feet in the area of the major recharge source (east side of map in Figure 10A), the agricultural area northeast of the mine site, also represents the low precipitation conditions experienced over the last three years.

During the June 2002 period when these water elevation measurements were made, the pumping rates for the PW wells were:

WELL	AVERAGE PUMPING RATE (gpm) June 2002
PW-1	11.41
PW-2	8.27
PW-3	6.64
PW-4	7.53
PW-5	3 (estimated)
PW-6	2.83
PW-7	0.81
PW-8	0.10
PW-9	0.28
PW-10	0.22
PW-11	0.34

Pumping records for well PW-5 are not maintained due to mineral precipitation problems on the flow meter; the well averages about 3 gpm (Nick Hatfield, AHA; pers. comm., 2002). The total of the average pumping rates for the wells listed above in June 2002 is 41.41 gpm. This total includes PW-1, which was not included in the August/September 1999 total described above. Thus, there was less extraction of groundwater by the pumpback well system in June 2002 than in August and September 1999, particularly for PW-7 through PW-11. The lower extraction rates may be explained by the lowered water table on the northwest side of the mine site.

The contours were drawn in Figure 10A to include data from the more shallow completion of three sets of nested monitor wells (USGS-13 and W32DC; USGS-2B and W4CB; W5AB-2 and W5AB-3). In each of these nested pairs, the deeper completion (i.e., screen interval) results in a lower measured groundwater elevation. This condition suggests a downward vertical gradient in the shallow alluvial aquifer at the north end of the mine site, in which there is the potential for groundwater to move vertically downward as well as laterally, perpendicular to the contours shown in Figure 10A. The ability of groundwater to move vertically downward is a function of the vertical gradient and the vertical hydraulic conductivity of the alluvial materials, including the presence or absence of aquitards (e.g., clay layers) that can impede such movement.

The deeper portions of the alluvial aquifer flow system underlying the Yerington Mine Site were pumped to provide process water during mining operations, which likely resulted in groundwater flow toward the pumping wells in these deeper zones. Since the cessation of industrial pumping in 1978, flow directions in the deep aquifer have presumably resumed a more northerly flow direction (Seitz, et al, 1982). Data are not available to characterize groundwater flow conditions in the deeper portions of the alluvial aquifer.

Available groundwater elevation hydrographs for the monitor wells shown in Figure 8B are presented in Appendix B. The information used to create the hydrographs is contained within the mine site database maintained by Brown and Caldwell for Atlantic Richfield.

1.3.3 Climate

Huxel (1969) summarized the climate of the Mason Valley area as arid to semi-arid. Precipitation generally occurs as winter snows in the mountain blocks, and summer thundershowers both on the mountains and valley floor. Precipitation averages 20 inches in the mountains and 5 inches on the valley floor. Huxel (1969) cited an evaporation rate of approximately 4 feet, and described prevailing winds and storm trajectories that cross the valley as being generally from the west. The estimated pan evaporation rate for the site is about 37 inches per year based on data from Fallon, which has a similar climate (Piedmont Engineering, 2001). The precipitation and evaporation data indicate a water balance strongly dominated by evaporation, resulting in a net loss condition for the valley floor and lower alluvial fan areas where the Yerington Mine site is located. Atlantic Richfield is currently collecting site-specific meteorological data in the area of the pumpback wells.

1.3.4 Groundwater Budget

Recharge to groundwater in the valley-floor deposits in Mason Valley results from the percolation of runoff from snowmelt and extreme rainfall events, direct precipitation and recharge from the Walker River and irrigation canals and ditches. Huxel (1969) estimated the recharge from precipitation (runoff and direct) to the valley-floor aquifers at only 1 percent of the total annual precipitation in the Mason Valley hydrographic basin. In his water budget calculations for the basin, Huxel estimated approximately 2,000 acre-feet per year (3 percent of total) is recharged from precipitation to the valley-floor aquifers and 70,000 acre-feet per year (97 percent of total) is recharged from the river and associated agricultural diversions. In the basin-and-range province in western Nevada, little or no recharge from direct precipitation on the valley floor is allocated in hydrographic basin water budgets (e.g., Maxey and Eakin, 1949). Huxel (1969; Table 12) indicated that less than 0.1 percent of the basin groundwater budget, or less than 100 acre-feet per year, of total recharge occurs by direct precipitation on the valley floor.

The minimal amount of estimated recharge from direct precipitation on the valley floor results from a combination of low precipitation rates (5 inches or less) and the large evapo-transpiration (ET) capacity of the soils and native vegetation in Mason Valley. Huxel (1969) estimated that 57,000 acre-feet per year (79 percent of total recharge) of shallow groundwater tapped by phreatophyte roots would be discharged to the atmosphere. Additional groundwater discharges result from well pumping (municipal, industrial, agricultural and small domestic wells) and agricultural drainage canals. The water budget estimates provided in Huxel (1969) were tabulated for the entire Mason Valley, and these values represent general boundary conditions for the Yerington Mine Site and preliminary study area for the conceptual hydrogeologic model.

1.3.5 Surface Water Hydrology

The principal source of water in Mason Valley is streamflow in the Walker River system (Huxel, 1969). The East and West Walker Rivers originate in the Sierra Nevada, fed by melting snow, and merge south of the mine site (Figure 1). The Walker River flows northward through the valley to Walker Gap, where it turns eastward and then southeastward to Weber Reservoir and ultimately to its terminus to Walker Lake. The Walker River Irrigation District (WRID) was organized in 1919 to allocate Walker River diversions in Nevada, and the U.S. District Court defined existing water rights on the river in Mason Valley and throughout the Walker River basin (Huxel, 1969).

Streamflow data on the Walker River in the Mason Valley area have been collected intermittently since 1895, and continuously since 1947 (Huxel, 1969). In general, the greatest volume of runoff in the Walker River basin occurs during the period from March to July, when the winter snowpack in the Sierra Nevada thaws. Exceptions to this pattern occurred during winter flood events that occurred in 1937, 1950, 1955, 1963 and 1997 as a result of warm rain on the mountain snowpack. These winter floods are usually of high intensity and short duration, and do not typically produce the total volume of surface flows from spring snowmelt (Huxel, 1969). The large volume of snowmelt runoff provides irrigation water, and seasonal storage upstream of Mason Valley for use later in the irrigation season.

Huxel (1969; Table 7) presented surface water flow (i.e., gaging station) data for the period from 1948 to 1965 that indicated average streamflow losses of approximately 109,300 acre-feet from where the West and East Walker Rivers enter Mason Valley to where the Walker River exits at Walker Gap. This value is approximately 50 percent of the average surface flows entering Mason Valley for the period of record. These data include the complex network of agricultural diversions, although irrigation return flows were not well quantified. Huxel (1969; Table 8) also presented surface water flow measurements from specific reaches of the East Walker River, West Walker River and the main stem of the Walker River that indicated streamflow gains in March and November, and streamflow losses in May, June and September. The USGS has not collected surface water flow data for stream losses or gains (i.e., seepage runs) in the Walker River in the Yerington area (Russ Plume, U.S. Geological Survey; pers. comm., 2002).

1.3.6 Agricultural Applications

Acreage under irrigation in Mason Valley increased from about 12,000 acres in 1940 to 15,300 acres by 1945, and to 23,400 acres by 1965. Huxel (1969; Table 11) presented information for water use and acreage in Mason Valley for the period from 1880 to 1965, indicating that an average of about 140,000 acre-feet per year were diverted to irrigate about 30,000 acres of cropland. Huxel estimated that 41,000 acre-feet per year was consumed by the crops and pasturelands, and that the difference of approximately 100,000 acre-feet consisted of return flows to the river, seepage losses from canals and laterals, and evapo-transpiration.

Huxel recognized that return flows to the river in the upper reaches of Mason Valley were re-diverted into downstream canals and ditches, such that some of water was measured twice in his analysis. Specifically, in the Yerington sub-area, approximately 9,700 acres of cropland and pasture were irrigated by an average of 12,200 acre-feet.

1.3.7 Well Pumping

Huxel (1969) summarized well pumping information for municipal, industrial and irrigation uses in Mason Valley. Groundwater pumping associated with mining and milling operations at the Yerington Mine average approximately 3,400 acre-feet per year and other industrial uses were estimated at less than 100 acre-feet per year. The city of Yerington pumped approximately 550 acre-feet in 1966 to supply 610 users. Rural pumping for domestic and stock watering uses was estimated to be about 400 acre-feet in 1965. More current well pumping data, as available, for the area associated with the mine site will be acquired as part of the investigations conducted under this Work Plan.

Average gross and net values for pumping of groundwater for irrigation use were estimated by Huxel (1969; Table 15) for the period between 1959 and 1965 (including the 1959 to 1962 drought period) as 70,000 acre-feet and 46,000 acre-feet, respectively. The difference between gross and net pumping is the amount of pumped groundwater that returns to the valley-floor aquifer (approximately one-third of the gross value). Huxel (1969; page 36) concluded that the localized pumping by the Anaconda Company at the Yerington Mine caused little change to the groundwater regime in the adjacent area of the valley. As noted previously, this conclusion appears to differ from that of Seitz et. al. (1982) with respect to the importance of mine-related pumping to the observed change in groundwater elevation contours reproduced as Figures 3 and 4 of this Work Plan.

Pumping and application of groundwater from deeper portions of the alluvial aquifer for irrigation water is an important influence on groundwater conditions in the northern portion of the mine site. At the present time, the amount and quality of groundwater pumped and applied is not available. This information, as available, will be collected as part of this Work Plan. Groundwater extraction data from the pumpback well system along the northwest portion of the mine site are presented in Appendix B.

1.3.8 Groundwater Quality

Huxel (1969; page 44) characterized the chemistry of surface water flows entering Mason Valley as a calcium-bicarbonate type, and the chemistry of flows exiting the valley as a "more concentrated sodium-calcium-bicarbonate type with much greater portions of sulfate and chloride". "The increase in both dissolved solids and volume of flow within the valley, along with pronounced increases in sodium, sulfate and chloride all indicate that the river was receiving significant contributions of groundwater during the sampling period. Groundwater is contributed by lateral and upward percolation into canals, drainage ditches, and the river" (Huxel, 1969; Table 23).

Huxel (1969) recognized that groundwater quality varied from calcium-bicarbonate types to sodium-sulfate types in the valley-fill alluvium as a function of depth, lateral position, and texture and composition of the aquifer materials. He concluded that groundwater in Mason Valley with the greatest concentration of total dissolved solids (based on specific conductance measurements) resulted from cultural activities such as the recycling of irrigation water and discharges of mine process water (i.e., acid and tailings fluids) elevated in iron and sulfate. Huxel (1969) was able to correlate areas of low specific conductance with high sand and gravel grain sizes in the valley-fill alluvial materials, and indicated that "substantial quantities of good-quality surface water are able to infiltrate the valley fill during high flows". "The high specific conductance of water from shallow wells, auger holes and drainage ditches in the Wabuska sub-area reflects the concentration of salts caused by substantial natural discharge."

Huxel (1969; page 52) also recognized that "agricultural development in a basin having areas of natural ground-water discharge and inadequate drainage usually is accompanied by a deterioration of water quality". Waterlogged alluvium in the Wabuska sub-area was noted to have increased the amount of evapo-transpiration losses by phreatophytes, which has caused the accumulation of salts in the soil and shallow aquifers. Huxel estimated salt losses from the river to the valley-fill aquifers (i.e., accumulations in groundwater) in the range of 12,000 to 20,000 tons for the drought period from 1960 to 1962. Some percentage of accumulated salt would exit Mason Valley as "windblown dust or, to a lesser extent, as components of exported crops".

Seitz et. al. (1982) documented hydrogeochemical conditions down-gradient of the Yerington Mine site from 1976 through 1978. The USGS studied the extent of possible groundwater contamination by drilling monitor wells located north and northeast of the tailings ponds (17 wells at 13 locations shown in Figures 7A and 7B of this Work Plan). Shallow wells were screened in the shallow unconfined alluvial aquifer, "within the uppermost five feet of saturated sedimentary deposits". Deeper monitor wells were constructed at four of the 13 locations (sites 1, 2, 4 and 5) with screen intervals from 27 to 29.5 feet below ground surface (bgs). The deeper wells were designated 1A, 2A, 4A and 5A (Seitz, et. al. 1982). Groundwater samples were collected for chemical analysis from the wells and mine process fluids in 1978.

Seitz et. al. (1982) also characterized process waters from the mine site, including tailings water from the recycling ditch, seepage from the tailings pond and residual brine from one of the evaporation ponds: "The alkaline tailings fluid contains about 1,100 mg/L of dissolved solids dominated by calcium and sulfate, with only small concentrations of elements such as copper that normally are constituents of natural water". "Seepage from the tailings pond is likewise dominated by calcium and sulfate, but it has a much lower pH, a somewhat greater dissolved-solids concentration (about 1,500 mg/L), and much greater concentrations of copper and zinc. The seepage presumably represents tailings water that has changed chemically during percolation through the tailings pile."

Seitz et. al. also evaluated groundwater quality data from six Anaconda water-supply wells located down-gradient from the tailings and evaporation ponds. These wells are screened at depths ranging from 50 to 455 feet below the land surface and were sampled by Anaconda from 1974 to 1979. Of the six wells, four showed an increase in TDS concentration over the sampling period. Increases in calcium and magnesium relative to sodium in the wells showing increasing TDS were attributed to percolating acid waste fluids dissolving carbonate minerals and ion exchange with clay minerals. Seitz et. al. (1982) concluded that contaminated shallow groundwater was a localized occurrence, within 0.2 miles down-gradient of the ponds. This study recommended continued monitoring of the shallow and deep aquifers.

Seitz et. al., (1982) concluded that the influence of deep aquifer pumping had induced the downward migration of mining-impacted shallow groundwater. "Deeper ground water nearest the waste-disposal ponds has deteriorated appreciably in quality during the period of heavy pumping, and geochemical evidence implicates the acid brine or acidic percolation from the tailings ponds, or both. The areal extent and severity of deeper contamination are as yet limited." Seitz also states that, with changes in the direction of groundwater flow following the cessation of industrial pumping, slightly to moderately contaminated deeper groundwater may spread in a down-gradient (i.e., northward) direction.

Two monitoring wells, W5AB-1 and W5AA-1 (Figure 8B), have been used to represent groundwater quality in the deeper alluvial aquifer since 1983 (Piedmont Engineering, 2001). Time-concentration plots of dissolved iron and sulfate in these two wells over the period of record indicate that further degradation of the deep aquifer has not occurred (Piedmont Engineering, 2001). Additional data would improve the understanding of the potential down-gradient migration of impacted groundwater in deeper portions of the alluvial aquifer.

Applied Hydrology Associates (AHA, 1983) examined hydrogeochemical conditions in the area north of the Yerington Mine site in 1983, including sampling and analysis of groundwater from USGS test wells and selected domestic wells. Surface water samples from five locations along the Wabuska Drain were also collected for chemical analysis. In addition, AHA collected material samples from surface mine units including tailings and evaporation ponds, and three locations along the Wabuska Drain for leach testing. Leach tests were performed on these samples to gain some idea of the potential contaminants that may be associated with water percolating through these materials and entering the groundwater system below these locations.

Analytical results from these investigations were compared in AHA (1983) to the results presented by Seitz et. al. AHA documented increased sulfate and TDS concentrations for most wells, particularly USGS wells 2B, 7 and 13. However, AHA noted that TDS and sulfate concentrations rapidly declined with increasing distance from the evaporation pond area at the northern margin of the mine site. AHA also noted that increases in the concentration of copper, iron, lead and manganese in these wells were similar to the leachate from the evaporation ponds, suggesting that the leaching of evaporation pond sediments at some time may have been a potential source for groundwater contamination (AHA, 1983). This view was supported by oxygen and deuterium stable isotope analytical results from these wells, which indicated that groundwater mixed with highly evaporated water.

Domestic wells sampled by AHA (1983) in the northeastern portion of their study area did not show evidence of contamination. AHA also sampled surface water from four locations in the Wabuska Drain adjacent to the tailings and evaporation ponds at the northern margin of the mine site. The Wabuska Drain, described in more detail in Section 1.3.9 and the Draft Wabuska Drain Work Plan (Brown and Caldwell, 2002b), was designed to intercept shallow groundwater in the alluvial aquifer. The general chemical trend for the four Wabuska Drain samples near the mine was an increase in TDS and most major ions in the direction of flow (AHA, 1983). Calcium decreased slightly in the direction of flow and bicarbonate decreased, coincident with a decrease in pH. In addition, there was an increase in iron, manganese and copper in the direction of flow in the Drain. Subsequent NDEP sampling of this area near the mine (reviewed in Brown and Caldwell, 2002b), showed that water quality samples from Drain locations progressively north of the mine site improved in quality.

McGinnis and Associates (2000) reviewed the above hydrogeologic and groundwater quality studies at the Yerington Mine site, and summarized associated groundwater quality data from various sources. This report concluded that the distribution of constituents of concern in groundwater could not be accurately determined with currently available data. This report also concluded that the pumpback well system has not contained impacted groundwater and further studies are needed to define the extent of the plume.

Piedmont Engineering (2001) evaluated the plume of contaminated groundwater at the northern margin of the mine site. Contour maps that compare pH, sulfate and iron concentrations between 1986 and 1999 indicate that, for the 13-year period of pumpback well system operations:

- The extent of lower pH values (4, 5 and 6 standard unit-contours) retracted back towards the interior of the northern portion of the mine site (Figures 11A and 11B of this Work Plan);
- Sulfate concentrations, using the 1,000-mg/L contour as the basis for comparison, did not noticeably change (Figures 12A and 12B of this Work Plan); and
- Iron concentrations, using the 100-mg/L contour as the basis for comparison, did not noticeably change (Figures 13A and 13B of this Work Plan).

The National Applied Resource Sciences Center (NARSC) of the U.S Bureau of Land Management conducted two surface geophysical surveys in April 1999 (electromagnetic induction and direct current electrical resistivity) to evaluate the extent of a “groundwater plume” of conductive groundwater associated with the mine site (NARSC, 1999). The “plume” was interpreted to reside in the uppermost alluvial aquifer with potential localized impacts in the intermediate alluvial aquifer. NARSC (1999) interpreted the “plume” to extend north over 4,000 feet from the mine site boundary. Beyond this distance, the “plume” was not detectable due to a gain in topographic elevation, a decrease in constituent concentrations and/or an increase in depth to water. The uncertainty of the geophysical information at this northern boundary of the survey may have resulted from the lack of supportive information (e.g., drill logs for use in calibrating surface results). NARSC concluded that the pumpback well system may not be preventing a “continued release to down-gradient areas” and recommended supplemental investigations to provide for a more complete understanding of the survey results.

Additional groundwater quality data from the area north of the mine site (covered by the NARSC geophysical surveys) was acquired by hydropunch sampling in 1999 (Piedmont Engineering, 2001). Sulfate concentration data from this sampling event (e.g., HP-23, HP-04, HP-21 and HP-25) shown on Figure 6 of the Piedmont Engineering report, and reproduced as Figure 12B of this Work Plan, suggests that the extent of groundwater north of the mine site with elevated sulfate concentration is generally limited. Because sulfate is the primary constituent of Total Dissolved Solids (TDS) in groundwater associated with the mine site, and TDS can be directly correlated to the electrical conductivity of groundwater, the sulfate data collected in 1999 do not support the NARSC conclusions regarding the extent of the plume north of the mine site.

The Superfund Technical Assessment and Response Team (START, 2000 and 2001) prepared a Site Assessment and Final Report that indicated concentrations of groundwater sampled and analyzed from monitor well MW-5, located along the southwest margin of the unlined evaporation pond (Figure 2), exceeded the primary maximum contaminant levels (MCLs) for arsenic, beryllium, cadmium, chromium, lead and selenium. The occurrence of these constituents in groundwater associated with the mine site will be evaluated as part of this Work Plan.

Groundwater quality data from all available referenced sources in this Work Plan are summarized in Appendix C, provided as a CD-ROM, derived from the mine site database maintained by Brown and Caldwell for Atlantic Richfield. In addition to pH, constituents that have been used to identify groundwater effects from historic mining operations and current conditions include iron and sulfate (e.g., Figures 11A through 13B). The presence of other constituents in groundwater that exceed primary maximum contaminant levels (MCLs), such as the possible constituents of concern (COCs) identified in the START (2001) report (arsenic, beryllium, cadmium, chromium, lead and selenium), will be investigated as part of this Work Plan to determine if they result from mine-related impacts, from other non-mining activities, or from ambient groundwater conditions.

Tables 4 and 5 present water quality data for the site wells and for the domestic wells, respectively, sampled in June 2002 (note that some domestic wells are subject to a confidentiality agreement between the owners and the EPA, and data from these wells are not presented in this Work Plan). The locations of these wells are shown in Figures 8B and 8C, respectively. Analytical results for dissolved constituents from the June 2002 sampling event for site wells (Table 4) indicate that the area delineated by the 1,000 mg/L sulfate contour (Figure 6 of the 2001 Piedmont Engineering report; Figure 12B of this Work Plan) is generally similar to the area of mine-related groundwater shown in Figure 14. This area is also characterized by low pH and elevated concentrations of TDS and iron. Other potential constituents of concern (i.e., those that locally exceed primary MCLs in one or more site wells sampled in June 2002) include nickel, lead, fluoride, copper, chromium, cadmium and beryllium. The northern extent of the area shown in Figure 14 extends beyond the pumpback well system, but is limited by the analytical results from monitor wells MW2002-2, W5BB, MW2002-1, USGS-13 and W5AA-1.

TDS and sulfate concentrations that exceed 2,000 and 1,000 mg/L, respectively, may not be associated with mine-related impacts to groundwater at the site. These values may represent "ambient" groundwater quality at the site, an hypothesis to be tested as part of this Work Plan.

The sporadic occurrences of arsenic concentrations above 0.01 mg/L in the sampled monitor wells may not be directly associated with groundwater impacts beneath the site. Naturally occurring arsenic, at the concentrations reported for the Yerington Mine Site, in groundwater in western Nevada is common (e.g., Reno, Washoe County, Carson City, Douglas County, Fallon) and is not necessarily associated with base or precious metals mining. Arsenic occurrences associated with the mine site will be investigated as part of this Work Plan.

Analytical results (total concentrations) from domestic wells sampled in June 2002 (Figure 8C and Table 5) indicate the following:

- Six domestic wells northwest of the mine site, including the Phipps well, have neutral pH values (7.84 to 8.26), TDS concentrations in the range from 310 to 860 mg/L, sulfate concentrations in the range from 53 to 330 mg/L, and arsenic concentrations in the range from 0.03 to 0.044 mg/L.
- One domestic well north of the mine site (WDW-19) showed neutral pH (7.44 s.u.), TDS at 840 mg/L, sulfate at 270 mg/L, and arsenic at 0.004 mg/L.
- One domestic well DW-43, located northeast of WDW-19, showed neutral pH (7.49 s.u.), TDS at 410 mg/L, sulfate at 76 mg/L, and arsenic at 0.004 mg/L.
- One domestic well between the mine site and the Sunset Hills sub-division (DW-04) showed neutral pH (7.79 s.u.), TDS at 1,000 mg/L, sulfate at 440 mg/L, and arsenic below detection (0.001 mg/L).
- Domestic wells in the Sunset Hills sub-division have neutral pH values (7.49 to 8.04), TDS concentrations in the range from 390 to 980 mg/L, sulfate concentrations in the range from 130 to 290 mg/L, and arsenic concentrations in the range from 0.016 to 0.018 mg/L.

Based on these analytical results, and the assumption that elevated ambient TDS, sulfate and arsenic concentrations in this part of western Nevada are common occurrences, it appears that none of the domestic wells sampled in 2002 have been affected by mine-related water from the Yerington Mine Site.

1.3.9 Related Surface Water Features

Two surface water features that are strongly linked to groundwater conditions at the Yerington Mine Site are briefly discussed in this section. These features are the Yerington Pit Lake and the Wabuska Drain, and both are subjects of specific Work Plans that will be developed pursuant to the SOW.

Yerington Pit Lake

The Yerington Pit Lake is currently the subject of a Ph.D. dissertation by Mr. Ron Hershey of the University of Nevada, Reno (UNR) and the Desert Research Institute (DRI), affiliated with UNR. In addition, PTI Environmental Services (PTI, 1997) published the results of a study performed on the Yerington Pit Lake (Anaconda Lake, one of three pit lakes evaluated in this study). The University of Utah conducted additional pit lake studies for the NDEP.

The Yerington Pit intercepts groundwater flow from the bedrock and alluvial flow systems at the southern end of the mine site (Figure 2). As a result of mitigation efforts to reduce the impact of Walker River flooding in the Yerington area in 1997, floodwaters were diverted into the pit. Subsequent attempts to eliminate the diversion have not been completely successful, and seepage from the river through the alluvium surfaces within the pit highwall and flows into the pit lake at rates of approximately 100 to 120 gpm. In addition, groundwater inflows into the pit from the alluvial aquifer occur along the bedrock-alluvium contact at rates up to approximately 50 gpm, and inflows from the bedrock groundwater flow system occur at unknown rates. Additional inflows occur as direct precipitation and associated highwall runoff. Pit water lost to the atmosphere by evaporation is the final water balance component of the Yerington Pit.

Wabuska Drain

The Wabuska Drain is an agricultural return-flow drain located in northern Mason Valley, Lyon County, Nevada. The Drain originates immediately north of the Yerington Mine Site and is aligned to the north past its intersection with the West Campbell Irrigation Ditch, and through the Paiute Indian Reservation. Further north, it crosses Highway 95A approximately one mile south of the town of Wabuska, where it is aligned to the east-northeast to its intersection with the Walker River north of the Mason Valley Wildlife Management Area. The Wabuska Drain is approximately 13.8 miles in length.

The Wabuska Drain operates by collecting runoff from crop irrigation and precipitation, and by intercepting rising groundwater in the shallow alluvium that rises to an elevation that intercepts its base. Rising groundwater levels result from natural recharge (seepage from the Walker River or direct precipitation) and/or cultural recharge (seepage from agricultural diversions such as the

Campbell Ditch and recharge from irrigated fields). In addition to direct runoff from irrigated fields, runoff from direct precipitation on roads, streets and highways also contribute to flows in the Drain. Depending on specific site conditions (e.g., time of year, precipitation and runoff events, climatic variations and agricultural practices), the Wabuska Drain can either serve as a recharge component to, or a discharge component from, groundwater in the preliminary study area.

1.4 Data Quality Objectives

In order to ensure that data of sufficient quality and quantity are collected to meet the project objectives, the four-step Data Quality Objective (DQO) process listed below was utilized to develop the activities described in this Work Plan:

- Step 1. State the Problem;
- Step 2. Identify the Decision;
- Step 3. Identify the Inputs to the Decision; and
- Step 4. Define the Boundaries of the Study.

The problem statement (Step 1) is as follows: "Groundwater conditions in the area of the Yerington Mine Site are not completely known, and available information is inconclusive with respect to the fate and transport of COCs in groundwater that may pose a risk to human health and the environment". This problem statement anticipates the conceptual hydrogeologic model components discussed in Section 2.0 that are based on the information discussed in Section 1.3, and the temporal and spatial attributes of groundwater quality at the site (also summarized in Section 1.3 and presented in Appendices to this Work Plan).

Step 2 of the DQO process (Identify the Decision) asks the key question(s) that this Work Plan is attempting to address: "What monitoring (including the installation of new monitor wells), sampling and analytical activities for locations around the Yerington Mine Site serve to evaluate the potential risk to the environment and human health, and support the development and evaluation of closure activities at the Yerington Mine site including the establishment of groundwater protection goals?" The criteria necessary to determine if the proposed Work Plan activities will answer this question include, but may not be limited to:

- Adequacy of collected data to document the fate and transport of COCs in the groundwater flow systems associated with the mine site at present, and COCs that may be sourced from surface mine units in the future;
- Adequacy of collected data to define "background" or "ambient" chemical concentrations in groundwater hydrologically up-gradient of the mine;
- Efficiency of the existing pumpback well system to capture COCs that may be migrating to possible receptors located down-gradient of the mine site;
- Effects of groundwater inflows (including seepage from the Walker River) to the Yerington Pit Lake on the fate and transport of COCs in the groundwater flow systems; and
- Effects of mine-related groundwater on surface water flows in the Wabuska Drain.

Step 3 of the DQO process (Identify the Inputs to the Decision) identifies the kind of information that is needed to address the question posed under Step 2. This information would include:

- Historical and future groundwater elevation and water quality data from monitor wells and production wells installed at appropriate locations at the site, and within the preliminary study area;
- Lithologic logs from borehole drilling during well installations;
- General site geologic data (e.g., Proffett and Dilles, 1984);
- Meteorological data to refine the site water balance and components of recharge and discharge in the preliminary study area;
- Well pumping rates from pumpback and other groundwater wells at the site;
- Well pumping rates and application rates of groundwater and application rates of surface water diversions used to irrigate adjacent agricultural areas that recharge shallow groundwater in the area north of the mine site;
- Pit lake elevation and inflow data for the Yerington Pit Lake that would support a pit lake water balance analysis (to be compiled under a companion Work Plan);
- Water quality data from surface water flows at appropriate locations in the Wabuska Drain that may be compared to groundwater quality and elevation data from proximal monitor wells;
- Materials characterization data, including soil moisture monitoring, from existing surface mine units (to be collected under this Work Plan and companion Work Plans).

Step 4 of the DQO process (Define the Boundaries of the Study) defines the spatial and temporal aspects of the field monitoring, sampling and analytical activities proposed in this Work Plan. The study area boundary shown in Figure 3 defines the area of data collection for inputs into the decision. The rationale for selecting the proposed study area boundary is based on the information presented in Section 1.3 and components of the conceptual hydrogeologic model, described below in Section 2.0.

The southern margin of the study area is defined by bedrock outcrops and alluvial fan deposits south of the mine site, and north of the town of Mason. The southern margin extends to the Walker River to the east and to the Singatse Range topographic crest to the west. This area would allow ambient or background groundwater quality to be characterized south of the mine site. This southern portion of the study area is understood to be up-gradient of the mine site, based on current knowledge of groundwater flow directions in this portion of the study area.

The western margin of the study area is defined by the topographic crest of the Singatse Range, to a point coincident with the southern margin of the Yerington Paiute Indian Reservation (Figure 3). The purpose of including this western area is the potential contribution of recharge from a portion of the Singatse Range to groundwater flow in the preliminary study area. The northern boundary of the study area is defined by the southern margin of the Yerington Paiute Indian Reservation. The extension of the study area to the southern boundary of the reservation is based on: 1) the concern that COCs in groundwater may reach the reservation; and 2) the recent installation of groundwater monitor wells by the Paiute Indian Tribe.

The eastern margin of the study area is variably defined by recharge features (the West Campbell Ditch, agricultural fields and the Walker River), and by the Singatse Spur. These recharge features provide local controls on the direction and gradient associated with groundwater flow in the shallow alluvial aquifer in the study area. The Singatse Spur is hypothesized to impede groundwater flow in the shallow alluvial aquifer and limit recharge from the Walker River to the area immediately north of the mine site. In the southeastern portion of the study area (e.g., in the area of the Yerington Pit), bedrock does not impede Walker River recharge to the alluvial aquifer and the Yerington Pit Lake.

The time frame for conducting the investigations described in this Work Plan will be based on a monitoring period to be agreed upon by the YTWG. The installation of proposed monitoring components (i.e., wells, piezometers, soil moisture probes) is anticipated to be completed by March 30, 2003. Monitoring activities will be conducted on a quarterly basis for one year.

SECTION 2.0
CONCEPTUAL HYDROGEOLOGIC MODEL

2.1 Purpose of Conceptual Hydrogeologic Model Development

The conceptual hydrogeologic model for the Yerington Mine Site describes groundwater conditions during the pre-mining and mining periods, and current conditions within the preliminary study area, a sub-region of the Mason Valley hydrographic basin. The model identifies the components of the sub-regional and site water balance, including relative recharge and discharge values. Improvements to this hydrogeologic model can refine the Conceptual Site Model that identifies potential contaminant sources, pathways and receptors. The objectives for developing this conceptual hydrogeologic model for the mine site include:

- Refining portions of the Conceptual Site Model, briefly summarized below;
- Creating groundwater flow and related water budget concepts for hypothesis testing; and
- Establishing a framework to conduct the site investigations described in Section 3.0.

A Draft Final Conceptual Site Model (CSM) was submitted to the Yerington Technical Work Group on August 29, 2002 for review, and will be revised and finalized pending the incorporation of review comments. The CSM flow diagram is reproduced in this Work Plan as Figure 15. The relationship between potential sources, media pathways and receptors for groundwater shown in Figure 15 is anticipated to be improved as the result of investigations proposed in this Work Plan.

2.2 Pre-Mining Conditions

Sources of information for an assessment of pre-mining groundwater conditions in the area of the Yerington Mine include Huxel's 1969 report, Proffett and Dilles' 1984 geologic map and cross sections (Figures 4 through 6), and a mosaic of 1938 aerial photographs of the area prior to mine development (presented as Figure 16). The following paragraphs generally describe pre-mining hydrogeologic conditions in the area of the mine site.

The outline of the future mine site is shown on Figure 16. An irrigation canal trends northwest through the site and supplies surface water diverted from the Walker River to the agricultural areas within, and west of, the northwest portion of the future mine site. Agricultural areas north of the future mine site are supplied by the West Campbell Ditch and other conveyance features. The town of Yerington and irrigated areas along the Walker River are shown on the right side of the photo mosaic.

The area of white salt (evaporite) deposits within, and north of, the northern portion of the future mine site is an area of shallow groundwater that is likely recharged from the surrounding agricultural areas. Based on descriptions by Huxel (1969), this area of evaporite deposits appears to represent a "waterlogged" area (darker colors in this area represents standing surface water). The occurrence of ponded water and evaporite salts at this location suggests that groundwater is immediately beneath the ground surface at this interface between coarser and finer sediments, where it was subject to evaporation and evapo-transpiration that concentrated and deposited dissolved salts at the ground surface (e.g., a playa environment). Thus, prior to the startup of copper mining operations in 1953, the northern portion of the future Yerington Mine Site appears to have been occupied by a groundwater discharge area. As seen in the 2001 aerial photograph base in Figure 2, these salt deposits remain in the area north of the mine site.

This area of shallow groundwater and salt deposits is located at the transition of the alluvial fan developed along the range front of the Singatse Range, and where range-front faults have been mapped (Proffett and Dilles, 1984). Figure 17 is a map of pre-mining hydrogeologic conditions that shows the location of these range-front faults (dotted black lines) as well as bedrock occurrences (brown-colored areas). Figure 17 also shows the extent of Pleistocene Lake Lahontan lacustrine deposits (purple line; from Reheis, 1999), the future mine site (red line) and the outline of agricultural areas (green line from the 1936 aerial photo mosaic). The Walker River, Campbell Ditch system and Wabuska Drain are also shown on Figure 17.

The future mine site is located within the topographic and geologic transition from an alluvial fan, located on the east side of the Singatse Range and developed along "The Canyon" drainage below Mickey Pass (as shown on the 1987 U.S.G.S. topographic map), to the valley floor (Figure

17). Alluvial materials present in “The Canyon” drainage may be a focused area of recharge from the mountain block to the valley floor. The lithologic materials present in this transition area include relatively coarse-grained alluvial fan sediments, primarily beneath the southwest portion of the future mine site, and fine-grained lacustrine and flood plain (valley-fill) sediments beneath the northeast portion of the site.

As shown on a portion of the 1984 geologic map and associated cross sections, reproduced as Figures 4 through 6, the southern portion of the future mine site is located within a northeast-trending structural block, or spur, of the Singatse Range, between the main range front and the Walker River. The northern portion of the future mine site is located between the Singatse Spur and the alluvial fan, and was covered by a veneer of Quaternary alluvial sedimentary deposits. These deposits covered most of the Singatse Spur structural block, which outcrops near its northeast margin as McLeod Hill and other exposed bedrock occurrences. Existing highwall exposures in the Yerington Pit indicate that the pre-mining thickness of alluvium in this area of the mine site was on the order of a few tens of feet, and thickened to the west and north. This increase in alluvial thickness is also shown in Figures 5 and 6.

Groundwater flow conditions in the bedrock of the Singatse Range and Singatse Spur are poorly known, as is the extent of hydraulic communication between bedrock and alluvial flow systems. However, if the hydrogeologic character of the bedrock associated with the Yerington ore deposit is similar to most or all hardrock mine sites in Nevada, groundwater flow in these intrusive and volcanic rocks will likely be controlled by fractures and boundary conditions resulting from faults and lithologic (e.g., intrusive) contacts. Groundwater wells used to de-water the Yerington Pit likely tapped major water-bearing structural zones, and post-mining groundwater inflows into the pit likely occur from these same fractured zones (as discussed below in Section 2.3).

Recharge to bedrock groundwater flow beneath the site from the Singatse Range results from the percolation of precipitation and runoff through the fractured bedrock. Recharge to alluvial groundwater beneath the site occurs as a result of direct percolation of meteoric water through the alluvial fan materials from precipitation and runoff. Recharge from direct precipitation on the valley floor is considered negligible (Huxel, 1969). Because of the low elevation and limited areal extent of the bedrock on the eastern margin of the site, no recharge from this area is considered likely.

Along the southern margin of the future mine site, recharge to the alluvium from the adjacent Walker River (Figures 2 and 17) occurs as a result of the river losing water through seepage (the present day flow of water into the Yerington Pit from the river is a focused example of this seepage). As the river flows to the northeast past the town of Yerington (Figure 5; cross section A-A'), the structurally uplifted block of bedrock (i.e., spur of the Singatse Range) likely impedes recharge from the Walker River to the alluvium underlying the northern half of the future mine site. Recharge from the Campbell Ditch (Figure 17) east of the Singatse Spur would also be impeded by this bedrock occurrence.

Irrigated agricultural fields are evident to the northeast of the site in the 1938 aerial photo mosaic (Figure 16), and an area of irrigated agriculture is also evident underlying a part of what is now the northwest portion of the future mine site. As described below, these agricultural areas are hypothesized to have been the dominant recharge component to this portion of the future mine site. The former agricultural area that is currently covered by the Oxide Tailings Area (Figure 2) may have been an important recharge source to the southern portion of the groundwater discharge area.

In addition, the geologic map shown in Figure 4 indicates that the Sales Fault (also depicted in Figure 17) occupies the area where ponded water and evaporative salt deposits were present in 1938. This fault and the transition from fine-grained to coarse-grained alluvial materials may be important factors in creating the groundwater discharge area observed in the 1938 aerial photographs.

As described in Section 1.3, Huxel (1969) estimated the following recharge components to the Mason Valley hydrographic basin based on the Maxey-Eakin method:

- 3 percent is recharged from precipitation that falls on the surrounding mountain ranges;

- 97 percent is recharged from the river and associated agricultural diversions; and
- Less than 0.1 percent is recharged from direct precipitation on the valley floor.

The thickness of alluvium in the area of the future mine site generally increases from south to north, consistent with the development of alluvial fan and flood-plain/lacustrine depositional environments away from the Singatse Range front. At the location of the Yerington Pit, the depth of unconsolidated alluvial sediments is a few tens of feet. In the vicinity of the tailings areas at the northern margin of the site, the thickness of the alluvium exceeds 500 feet.

The pre-mining hydrogeologic conditions described above are summarized in Figure 17. Sources of groundwater recharge to the alluvial aquifer beneath the future mine site include the Walker River at the southeastern margin of the site, alluvial fan flow at the southwestern and western margins of the site, and recharge from agricultural areas and the conveyance ditches located southwest and northeast of the area of groundwater discharge and evaporite deposits. The Wabuska Drain served as a line “sink” for elevated groundwater (i.e., high water table resulting from agricultural applications of surface water) to be discharged into the surface water agricultural drain for return flow to the Walker River. The timing and extent of groundwater pumping for agricultural applications will also be investigated as part of this Work Plan, as available.

Conceptually, application of water for irrigation in the agricultural areas creates groundwater mounds during the nominal six-to-seven month growing season (April through September), which then dissipates during the remainder of the year (briefly discussed in Section 1.3.2). A clear spatial relationship can be seen in Figure 17 between the source areas of agricultural and alluvial fan recharge relative to the groundwater discharge/evaporite area, outlined in yellow.

Given the much more significant volume of recharge to the alluvial aquifer beneath the future mine site from the river and the agricultural areas relative to the alluvial fan, based on the water budget developed by Huxel (1969), localized directions and gradients of groundwater flow beneath the future mine site may be hypothesized, as follows:

- Pre-mining groundwater flow in the alluvial aquifer would generally be to the north-northwest at the southern portion of the site. In this area, the gradient caused by river recharge would be greater than from the alluvial fan, and groundwater flow may have been more westerly up to a certain point.
- Where the bedrock outcrops of the Singatse Spur occur, groundwater recharge from the river would have been essentially eliminated. However, recharge from the West Campbell Ditch would have continued to the north.
- It is unlikely that hydraulic communication between the alluvial and bedrock aquifers was significant (i.e., seepage into the bedrock from overlying alluvium would likely have been minimal). This hypothesis is based on similar hardrock mining sites in Nevada, and is not supported by site-specific data.
- Groundwater flow in the alluvium beneath the future mine site would generally flow to the north or northwest. Flow beyond the future mine site to the north during irrigation periods would likely have been affected by recharge from the large agricultural area to the north of the future mine site. Groundwater flow directions during the precipitation, snowmelt and runoff period could have been affected by recharge from the alluvial fan north of the groundwater discharge/evaporite area and by the dissipation of the mound beneath the agricultural areas.
- The relative influence of recharge sources on groundwater flow would vary on a seasonal basis. Precipitation, snowmelt and runoff events during the period from January through May likely interacted with the rate of mound dissipation beneath the agricultural areas to affect groundwater flow directions.
- Given the information presented in Figure 17, it is unlikely that shallow groundwater could have migrated outside of the groundwater discharge/evaporite area.

2.3 Groundwater Conditions During Mining

Groundwater flow conditions during mining operations are considered to have been generally similar to conditions prior to mining, with the following exceptions:

- Processing of copper ores on native or compacted ground resulted in the potential for process solutions and leachate to seep into the underlying alluvial aquifer.
- Elimination of the agricultural area underlying the Oxide Tailings Area.
- Dewatering of the Yerington Pit by perimeter and in-pit wells would have created dewatered and/or depressurized conditions in the fractured bedrock preferentially oriented along the structural elements exposed in the pit (e.g., west-northwest). The effect of bedrock dewatering operations on the alluvial groundwater flow system is uncertain.
- Exposure of the alluvium within the highwalls of the Yerington Pit caused some portion of groundwater flow in the alluvial fan to flow into the pit as a series of springs,

principally along the alluvium-bedrock contact (as seen at the present time along the western margin of the pit) rather than allowing it to flow to the northern portion of the site. Similarly, inflows derived from Walker River seepage along the eastern margin of the Yerington Pit resulted from exposure of the alluvium in this area.

- Groundwater pumping from six production wells completed to depths up to 455 feet below ground surface in the alluvium north of the mine site created a "cone-of-depression" in the alluvial aquifer. The effects of this pumping on shallow groundwater elevations in this area are uncertain, given the potential for relatively low vertical hydraulic conductivity values in the alluvium and/or the presence of clay zones (i.e., aquitards) that may confine portions of the deeper alluvial aquifer. Huxel (1969) noted that pumping by the Anaconda Company at the Yerington Mine caused little change to the groundwater regime in the adjacent area of the valley.
- Continuous ponding of process fluids in evaporation and tailings ponds, and associated ditches, in the northern portion of the mine allowed seepage from these ponds to infiltrate into the underlying alluvial aquifer. This seepage may have created very small and localized recharge areas, that would dissipate upon the cessation of mining activities.
- Arimetco mining operations involved leaching newly mined and previously stockpiled copper ores and tailings on HDPE-lined pads. Associated fluid management included the use of lined ditches and ponds. Seepage from these process components or from the Electrowinning Plant could have reached groundwater, but are not likely to have affected groundwater flow directions.

The evaporation and tailings pond areas were constructed immediately above, or adjacent to, the groundwater discharge/evaporite area shown in Figures 16 and 17. The alluvial fan to the west, the Walker River at the southern portion of the site, and the agricultural areas to the northeast of the site continued to serve as recharge areas. The Singatse Spur to the east continued to impede recharge from the Walker River and agricultural ditches.

The Yerington Pit intercepted alluvial recharge from the Walker River, and it is likely that some portion of this pre-mining recharge source was managed during pit operations. As in the case of pre-mining conditions, migration of alluvial groundwater to the area north of the mine site during mining operations were controlled by the build-up and dissipation of the groundwater mound beneath the agricultural recharge area northeast of the mine site and, to a lesser extent, the influence of recharge from the Singatse Range.

The net effects of mining operations on alluvial groundwater flow conditions is hypothesized to be: 1) the reduction of recharge from the south due to pit development; 2) the elimination of alluvial recharge from the pre-mining agricultural area under the present Oxide Tailings Area; 3) the creation of small, localized recharge areas beneath unlined evaporation ponds; and 4) the pumping of alluvial groundwater from the area north of the mine site to support mining and ore beneficiation operations. The net effects of mining operations on bedrock groundwater flow conditions are hypothesized to be the creation of a "cone-of-depression" within the bedrock groundwater flow system that modified flow directions. Depressurization of the bedrock flow system also likely occurred.

2.4 Post-Mining Groundwater Conditions

The following conditions are hypothesized to have affected post-mining groundwater flow at the Yerington Mine Site (Figure 18):

- Refilling of the Yerington Pit with groundwater from the bedrock and alluvial flow systems (the Yerington Pit Lake will be evaluated as part of a companion Work Plan). The pit lake is currently refilling and, when it reaches an "equilibrated" water balance condition, it's level will be controlled by recharge and discharge components. It is reasonable to assume that, like most other pit lakes developed in a high net evaporation setting, the Yerington Pit Lake will likely function as a groundwater sink characterized by a perpetual "cone-of-depression" in the bedrock aquifer. This condition will reflect the long-term pit lake water balance, where inflows (groundwater recharge plus direct precipitation) will be less than outflows (discharge to the atmosphere by evaporation) on an average annual basis.
- Installation of six groundwater pumpback wells in 1985 and subsequent improvements to groundwater management activities, including the installation of five additional pumpback wells and lining of the evaporation ponds in 1998. This groundwater management system extracted 80.3 acre-feet (26.1 million gallons) of shallow alluvial groundwater in 2001 from 11 pumpback wells (AHA, 2002). This volume of pumped groundwater to control off-site migration of mine-related groundwater in the shallow alluvial aquifer appears to be a significant percentage of the water budget in the shallow alluvial aquifer within the mine site (estimated below).
- Inactive process components (e.g., oxide and sulfide tailings, evaporation ponds, and other surface mine units) likely have sufficiently dried since 1978 to create enough moisture storage capacity to store and evaporate meteoric water that may fall as direct precipitation on the valley floor. These former sources of potential recharge to

groundwater are less likely, or no longer able, to source leachate to groundwater (to be evaluated in this and companion Work Plans).

- Arimetco leach pads have also been drying since operations ceased in 1999 (to be evaluated in a companion Work Plan).
- The existing agricultural recharge area located north of the mine site is somewhat smaller than pre-mining (1938) conditions, has a more regular (i.e., square) geometry, and does not extend as far north.

The differences between pre-mining and post-mining groundwater flow conditions in the area of the Yerington Mine Site are hypothesized to be: 1) the reduction of recharge to the alluvial aquifer from the south due to pit development; 2) the elimination of alluvial recharge from the pre-mining agricultural area under the present Oxide Tailings Area; 3) changes in the size of, and the amount of irrigation water applied to, the agricultural area northeast of the mine site; 4) the implementation of the pumpback well system at the northwest portion of the mine site; and 5) the refilling of the Yerington Pit with bedrock and alluvial groundwater. The effect of mining operations on groundwater quality is hypothesized to be the sourcing of certain constituents of concern from various process components located within the mine site.

Although there is likely some degree of resistance to vertical flow within the alluvial aquifer flow system created by the depositional layering of lacustrine and flood plain sedimentary deposits, and the existence of low-permeability clay layers in at least part of the mine site area, some downward migration of contaminated shallow groundwater may occur under the influence of agricultural pumping in the area north of the mine site. Agricultural pumping extracts groundwater from deeper portions of the aquifer system, which can induce a downward hydraulic gradient. The application of irrigation water on agricultural fields at the surface may compound the effects of agricultural pumping by locally raising the water level of the shallow aquifer and increasing the magnitude of the downward hydraulic gradient. It may also have the beneficial effect of reducing concentrations of constituents of concern that may be present in the shallow aquifer.

As described in Section 1.3.2, nested monitor wells at the northern margin of the mine site (USGS-13 and W32DC; USGS-2B and W4CB; W5AB-2 and W5AB-3) indicate the potential for groundwater to move vertically downward. The ability of groundwater to move downward is a function of the vertical gradient and the vertical hydraulic conductivity values of the alluvial materials including the presence or absence of aquitards (e.g., clay layers) that can impede such movement.

2.5 Conceptual Site Groundwater Budget

An assessment of the overall water budget for the study area will assist in understanding existing groundwater flow and water quality conditions, including the relative volumes and importance of recharge sources and discharge components for the shallow alluvial aquifer. The volumes discussed below are a first-order approximation, and are subject to improved quantification with the acquisition of additional data during the site investigations proposed in this Work Plan. The water budget information is, in part, summarized from the description of the hydrogeologic setting presented in Section 1.3.

<u>Groundwater Budget Recharge Components</u>

Groundwater is recharged to the aquifer system underlying the Yerington Mine Site through the same processes as those that recharge the remainder of the Mason Valley. These recharge processes are dominated by infiltration from the Walker River and from associated irrigation ditches and flood-irrigated fields (approximately 97 percent of total). Only minor recharge contributions (approximately 3 percent of total) occur from the adjacent mountain block, alluvial fan, and direct precipitation on the valley floor (Huxel, 1969). Conceptually, all of the nominal three percent value of total recharge is derived from precipitation in the Singatse Range at elevations that exceed 5,090 feet amsl (Daly et. al., (1994).

Although groundwater flow from up-gradient portions of the alluvial flow system generally may provide a substantial portion of the groundwater budget for most segments of the Mason Valley, this is not the case for the mine site area. As shown in Figure 4, the mine site is largely surrounded on the northern, eastern and western sides by bedrock, which limits alluvial groundwater underflow to the site. The very southwestern portion of the mine site receives recharge from the flood-plain alluvial deposits occupied by the Walker River, the northeast portion of the mine site receives recharge from the agricultural area, and the western portion of the mine site receives limited recharge from the mountain block and alluvial fan of the Singatse range (Figure 18).

The relatively small amount of groundwater recharged to the shallow alluvium beneath the mine site from the Singatse Range results from the infiltration of precipitation and runoff. A method for estimating the recharge to groundwater basins from precipitation in surrounding mountain blocks was developed by Maxey and Eakin (1949) for 13 basins in eastern Nevada. The Maxey-Eakin method assigns a percentage of the total annual precipitation falling on an area as groundwater recharge according to the magnitude of the average annual precipitation. For example, areas that receive greater than 8 inches of annual precipitation are assigned 3 percent of that precipitation total as recharge to groundwater. For areas that receive less than 8 inches of annual precipitation, 0 percent of that precipitation is estimated to become recharge.

The portion of the Singatse Range that is likely to contribute groundwater to the area of the Yerington Mine Site is estimated to be approximately 5,460 acres. This area (shown in Figure 3) was estimated by outlining the topographic divide of the range, including all of the range to the east of the divide to the contact with the alluvium. The north and south boundaries (Figure 3) were selected because groundwater recharge beyond these boundaries would have a negligible influence on the alluvial aquifer of the mine site area. The average annual precipitation for the contributing area is approximately 8 inches according to the 1996 Nevada State Precipitation Map (Daly, 1996). Using the Maxey-Eakin method, approximately 54 acre-feet per year is estimated to recharge the alluvial aquifer at the mine site from the Singatse Range.

Some percentage of recharge to the alluvial aquifer from the Singatse Range is now intercepted by the Yerington Pit highwall, and occurs as spring inflows into the pit lake above the alluvial-bedrock contact on the west side of the pit. Ron Hershey of the Desert Research Institute (pers. comm., 2002) has measured flows from a spring and visually estimated flows from subsidiary seeps on the west side of the pit in June and December of 2000. The large spring was measured at 50 gpm in June and 44 gpm in December, and the subsidiary seeps were estimated at 10 gpm during the summer and winter monitoring periods. Taking the sum of the average of the measured large spring flows (47 gpm) and the estimated 10-gpm seep inflow rate, the total inflow into the pit is approximately 57 gpm (92 acre-feet per year). Given the fact that the residential and commercial area of Weed Heights is located immediately above these springs and seeps on the west side of the pit, it is uncertain what contribution to these flows comes from natural recharge in the Singatse Range, and what is man-caused recharge from Weed Heights (e.g., water system leaks, infiltration of lawn watering, etc.).

As described above, the Walker River historically recharged the shallow alluvial aquifer at the southeastern portion of the site during pre-mining conditions. Ron Hershey (pers. comm., 2002) also measured flows from the major spring along the east side of the pit in June and December of 2000: 130 gpm in June and 81 gpm in December. The average of these two values is about 105 gpm (170 acre-feet per year). Joe Sawyer of SRK Consulting (pers. comm., 2002) has also measured seepage rates up to 120 gpm. A detailed assessment of the pit water budget will be conducted as part of the forthcoming Pit Lake Work Plan.

For the purposes of this water budget calculation, it is assumed that 170 acre-feet per year represents 80 percent of the total recharge value from the river and is assigned to pit seepage. The assumption that 170 acre-feet per year represents 80 percent of the total pre-mining recharge to the alluvial aquifer is based on the spatial position of the pit relative to the alluvial recharge area south of the Singatse Spur (Figure 18). The remaining 20 percent of the total recharge value (42 acre-feet per year) is assigned to recharging the alluvial aquifer north of the Yerington Pit Lake (between the pit and the bedrock outcrops along the Singatse Spur). The reduction of alluvial recharge that would otherwise flow towards the northwest margin of the mine site may result in lower groundwater elevations in the shallow alluvial aquifer at the north end of the site.

The groundwater recharge contribution from agricultural flood-irrigation and irrigation conveyances (e.g., the West Campbell Ditch) is the largest component of the groundwater budget for the study area. The area of the irrigated fields immediately to the north and northeast of the mine site (Figure 18) is calculated to be approximately 770 acres, and only half of this irrigated acreage may recharge the area north of the mine site (the other half of the recharge mound would be directed to the northeast). Using the standard Nevada State irrigation surface water right application rate of four acre-feet per acre per year, approximately 3,080 acre-feet is estimated to be applied to the agricultural land outlined in Figure 3 on an annual basis. This estimate does not include supplemental groundwater rights supplied by production wells in the alluvial aquifer, which would have the net effect of removing groundwater from deeper portions of the aquifer and replacing some percentage of the total volume removed back into the shallow portion.

Of the applied irrigation water, approximately three feet is assumed to be lost to evapo-transpiration for the months of April through September (Pennington, 1980). The remaining one-foot of water is estimated to either infiltrate to the shallow alluvial aquifer or be conveyed by agricultural return-flow drains (i.e., the Wabuska Drain). Assuming that 0.5 feet of applied water is allocated to groundwater recharge, the alluvial aquifer in the area north of the mine site receives approximately 193 acre-feet per year from the agricultural area shown in Figure 18.

The preliminary estimate for agricultural recharge is also an order-of-magnitude estimate based on the following uncertainties: actual application rates may differ from the assumed rate; the estimate of evapo-transpiration is taken from data for the Carson Valley; and the actual amount of groundwater removed from the shallow aquifer by the Wabuska Drain is unknown.

Groundwater Budget Discharge Components

Groundwater may leave the preliminary study area via the Wabuska Drain, evapo-transpiration, groundwater pumping (including operation of the pumpback well system), and evaporation from the Yerington Pit Lake. These outputs, or discharge elements, are described below.

The primary agricultural drain in the preliminary study area is the Wabuska Drain (Figure 18), which originates along the northern boundary of the mine site and flows to the north, eventually joining the Walker River north of the Mason Valley Wildlife Management Area. The Wabuska Drain was designed to intercept shallow groundwater during the irrigation season when the irrigation of agricultural fields creates groundwater mounding under the fields. During periods of no irrigation, or during irrigation periods with a depressed water table due to drought or other reasons (e.g., 1999 through 2002), the Drain is commonly dry north of the mine site. Some standing water, or flowing water of limited flow distance, from agricultural runoff has been observed on a weekly basis during the summer of 2002, an example of such a dry period when groundwater elevations were below the base of the Wabuska Drain.

With increasing distance away from the mine site, the volume of water that the Wabuska Drain conveys generally increases. Applied Hydrology Associates (AHA, 1983) measured surface water flows at four locations along the Drain in the area immediately north of the mine, and at one location where it crosses Campbell Road. These measurements were performed in March 1983. Recorded flow rates increased from 0.01 cfs (0.5 gpm) to 0.06 cfs (2.7 gpm) for the four locations near the site, and the flow rate at the Campbell Road location was 4.9 cfs (AHA, 1983).

Given that the Wabuska Drain only serves to drain the alluvial aquifer during periods of high groundwater levels, its current discharge value for the alluvial aquifer beneath the mine site is estimated to be zero. Under conditions experienced in March 1983 (i.e., relatively high precipitation year and prior to pumpback well installation), this discharge component would have been 2.7 gpm or 4.4 acre-feet per year. However, at the present time, groundwater elevations are well below the base of the Drain in the area north of the mine site.

Groundwater is removed from both the shallow and deep aquifers in the preliminary study area by pumping. At the Yerington Mine Site, groundwater is removed from the upper 50 feet of the shallow alluvial aquifer by the 11 pumpback system wells used to control the down-gradient migration of mine-related groundwater. The volume removed from the shallow aquifer by the pumpback wells in 2001 was approximately 26.1 million gallons (49.66 gpm) or 80.3 acre-feet (AHA, 2002).

Evapo-transpiration (ET) from phreatophytes in the remaining groundwater discharge area shown in Figure 18 will also discharge groundwater. Although no specific values for ET exist for this part of Mason Valley, an analogous site in central Lyon County was studied by the U.S. Geological Survey to establish groundwater budgets in specific sub-basins of the Dayton Valley hydrographic basin in the Carson River watershed (Maurer, 1997). ET values were estimated on the basis of groundwater depth, and ranged from 0.2 to 0.6 feet per year. For the remaining 268-acre discharge area north of the mine site and east of the agricultural area (the principal source of recharge to this ET discharge area), a value of 0.4 feet per year is assigned, resulting in an annual average discharge volume of 107 acre-feet.

To the north of the site, wells extract groundwater from deeper portions of the aquifer. Annual agricultural groundwater extraction volumes in this area are unknown, but the volumes are likely quite significant to the groundwater budget. A portion of the groundwater extracted by the agricultural wells is returned to the shallow aquifer through the infiltration of agricultural water, as described above.

Groundwater is also removed from the area of the Yerington Mine site through evaporation. The estimated pan evaporation rate for the site is about 37 inches per year based on data from Fallon, which has a similar climate (Piedmont Engineering, 2001). Evaporation removes groundwater from the site at the Yerington Mine pit lake and from the evaporation ponds at the site. More detailed information about evaporation from the pit lake will be presented in a forthcoming Work Plan focused on the Yerington Pit, as this discharge component primarily affects bedrock groundwater levels. As described above, excavation of the pit highwall has captured alluvial groundwater, which may be evapo-transpirated by vegetation within the pit and evaporated from the pit lake surface.

Evaporation and transpiration of groundwater occurs from areas of bare soil where the groundwater is near the surface and in areas of phreatophyte growth, respectively. Huxel (1969) estimated that approximately 57,000 acre-feet per year is removed from the shallow groundwater in the Mason Valley, primarily from the Wabuska sub-area. For the Yerington sub-area, the estimated evapo-transpiration loss was approximately 10,000 acre-feet per year from approximately 10,200 acre-feet of phreatophyte growth area.

The total area of phreatophyte growth and the potential evapo-transpiration flux directly from the mine site have not been estimated, but ET losses are conceptually set at zero for the purposes of the site water budget. Evaporation from the pumpback well ponds is already accounted for in the groundwater extraction discharge component. Therefore, the ET component of groundwater discharge at the site is limited to the remaining discharge area north of the mine site and west of the agricultural area (Figure 18).

Estimate of Groundwater Flow in the Shallow Alluvial Aquifer

For the upper 50 feet of the alluvial aquifer near the northern boundary of the mine site, Darcy's Law was used to estimate flow through a vertical plane (10,500-foot by 50-foot cross-sectional area, (shown as the "calculated groundwater discharge window" in Figure 18) using the following assumptions: hydraulic conductivity of 8 feet per day (AHA, 1999); hydraulic gradient of 0.0044 (from the January 1978 water level contour map in Seitz, et. al., 1982 and reproduced in this Work Plan as Figure 7A). The water levels from 1978 were measured prior to pumpback well installation.

The appropriate equation for this first-order estimate is:

$$Q = KiA$$

where:

Q = flow in cubic feet per day;

K = hydraulic conductivity in feet per day;

i = hydraulic gradient; and

A = cross-sectional area in square feet.

The resulting value of 18,480 cubic feet per day is equal to about 155 acre-feet per year. This order-of-magnitude estimate of underflow from the northern margin of the mine site in the upper 50 feet of the alluvial aquifer is influenced by the following assumptions:

- The hydraulic gradient was measured from January 1978 water levels, which may not accurately represent present-day conditions. However, these January water levels are not likely to reflect the influence of recharge from irrigating the adjacent agricultural fields.
- The hydraulic conductivity was calculated from reported transmissivity values determined from aquifer testing in six of the pumpback wells (AHA, 1999) based on an assumed aquifer thickness of 50 feet, which yielded a range of hydraulic conductivity values from 3 to 13 feet per day. The hydraulic conductivity is calculated by dividing the transmissivity (feet^2/day) by the aquifer thickness (feet).

The calculated value of 155 acre-feet per year represents the discharge component of shallow groundwater flow for the mine site groundwater budget when this portion of the alluvial aquifer is not influenced by recharge from the agricultural area at the northern margin of the mine site (i.e., completely dissipated recharge mound, and groundwater flows to the north at a gradient similar to that measured in January 1978) or by the pumpback well system.

The recharge and discharge components described above are integrated, on an acre-feet per year basis, into the following semi-quantitative water budget for the Yerington Mine Site:

CONCEPTUAL GROUNDWATER BUDGET	
Recharge Component	**Volume**
Singatse Range (Maxey-Eakin method)	57[1]
Walker River Alluvium	42[1]
Agricultural Irrigation	193
Total	**292**
Discharge Component	**Volume**
Underflow	75[2]
Pumpback Well Extraction	80
Agricultural Pumping	Unknown (deeper alluvium)
Evapo-transpiration	107[3]
Total	**262**

1 Some percentage of this value could percolate to alluvium deeper than the upper 50 feet of saturated thickness.
2 Calculated by subtracting the remedial pumping rate from the discharge rate estimated using Darcy's Law for the upper 50 feet of saturated thickness of the alluvial aquifer. Note that the total of 155 acre-feet per year discharge value is based on a gradient of 0.0044
3 Evapo-transpiration component estimated from the Dayton Valley Basin in central Lyon County.

Given that the recharge and discharge components are calculated to be within 10 percent of one another, the conceptual groundwater budget presented above appears reasonable as a first-order approximation (i.e., the assumptions used in the individual component calculations appear reasonable).

The budget difference of approximately 30 acre-feet per year does not imply that this volume of groundwater is migrating off site on an annual basis. For example, less recharge from one or more of the recharge components, or more discharge from agricultural pumping or evaporation would tend to equalize these estimated values. Estimated recharge values from the Singatse Range and from the Walker River presented above could conceptually be reduced due to percolation or direct recharge into deeper portions of the alluvial flow system. Presently, no information is currently available on the pumping rates of agricultural supply wells from deeper portions of the aquifer that may affect the shallow alluvial aquifer.

The budget presented above is focused on the shallow alluvial aquifer because that portion of the groundwater flow system is the most well known in the study area, and is subject to the principal recharge and discharge components (e.g., agricultural irrigation, evapo-transpiration and remedial pumping). The values presented for the recharge and discharge components may be summarized as follows:

- The total volume of groundwater flow in the shallow alluvial aquifer at the northern portion of the mine site and, in general, for the study area is relatively small;
- Shallow alluvial groundwater flow at the northern margin of the Yerington Mine Site is strongly controlled by agricultural recharge, and discharge from the pumpback well system and ET;
- The similar recharge and discharge values suggest that this first-order water budget reasonably approximates existing conditions, and supports the conceptual hydrogeologic model summarized below.

2.6 Conceptual Hydrogeologic Model Summary

Based on the information presented in Sections 1.3 and Sections 2.1 through 2.4, the following statements, or working hypotheses, relevant to the site investigations proposed in this Work Plan can be made about existing groundwater flow conditions at the Yerington Mine Site:

- Up-gradient recharge sources to the shallow alluvial aquifer include seepage from the Walker River through alluvial lacustrine and flood-plain deposits and underflow from the alluvial fan on the margin of the Singatse Range. Infiltration from the agricultural area (and the West Campbell Ditch) northeast of the mine site recharge this area.

- Direct recharge through surface mine units (e.g., waste rock or heap leach units) in their present "dry" condition is hypothesized to be negligible (to be confirmed by site investigations specified in this and companion Work Plans).
- Two major discharge features currently serve to remove groundwater at the north end of the mine site: the pumpback well system and evapo-transpiration from the remaining groundwater discharge area. The base of the Wabuska Drain is currently well above the 2002 water table, and groundwater inflows to the Drain will not occur until groundwater elevations rise due to "wetter" climatic conditions.
- Groundwater gradients and flow rates in the northern portion of the mine site are influenced by recharge from the agricultural area located northeast of the site. Conceptually, a seasonal groundwater mound would build up beneath this area during the irrigation season, and dissipate after agricultural applications of surface and groundwater cease in the fall. Until the mound dissipates, the groundwater flow direction north of the mine site appears to be towards the west, as depicted in Figure 10A. The direction of groundwater flow may shift to the northwest or, as observed in January 1978, to the north as a function of the mound dissipation rate and general groundwater flow conditions.
- The spatial relationship between the bedrock outcrops northwest of the mine site in the Singatse Range and the agricultural recharge area northeast of the site (Figure 18) suggest a relatively narrow (about 5,000 feet wide) migration path for mine-related groundwater to migrate north of the mine site under the effects of agricultural recharge. Potential recharge from the alluvial fan in this portion of the Singatse Range and the potential for the recharge mound beneath the agricultural area not to completely dissipate would further constrain this migration path.
- The Yerington Pit Lake is currently refilling with alluvial and bedrock groundwater. A pit lake water balance and related conditions will be evaluated in a companion Work Plan.

Based on the information presented in Section 1.3.8, the following statements (or working hypotheses) relevant to the site investigations proposed in this Work Plan can be made about existing groundwater quality conditions at the Yerington Mine Site:

- Groundwater quality beneath the mine site has been impacted by mine-related process solutions and operations. The geochemical signature of mine-related groundwater is not completely understood. However, based on their concentrations in process and tailings solutions, and the shallow groundwater beneath the site, iron, sulfate, and pH values have been used to generally type mining related groundwater impacts and "measure" containment and pumpback system effectiveness in the shallow alluvial aquifer (e.g., Piedmont Engineering, 2001; AHA, 2002).
- Based on 2002 monitor well analytical results, the following constituents of potential concern that exceed primary MCLs may also be present within mine-related groundwater

associated with the site: aluminum, nickel, lead, copper, chromium, cadmium and beryllium.

- Groundwater quality in the shallow alluvial aquifer north of the mine site is influenced by surface water and groundwater applied to the agricultural area. The water budget information in Section 2.4 indicates that at least half of the groundwater extracted by the pumpback well system comes from the agricultural area.
- Mine-related impacts to deeper portions of the alluvial aquifer are not entirely understood. Potential downward migration of COCs through the aquifer may be influenced by pumping from relatively deep wells and/or localized migration within boreholes or wells. However, water quality from intermediate to deeper wells remains primarily unimpacted with the exception of groundwater directly beneath the old unlined evaporation pond areas, and near well W5AA-1 where borehole migration may have caused potential cross contamination.
- The Yerington Pit Lake does not currently, nor in the future will, directly affect groundwater quality in the shallow alluvial aquifer. An indirect effect on alluvial groundwater quality is the reduction of recharge of presumably "good-quality" water to the flow system. A forthcoming Pit Lake Work Plan will evaluate these issues.

SECTION 3.0

WORK PLAN

This Work Plan describes site investigation activities that will improve the current understanding of groundwater conditions at the Yerington Mine Site and, in concert with companion Work Plans, to achieve the DQO's stated in Section 1.4. The proposed investigations will focus on providing data to achieve the following:

- Additional assessment of ambient or "background" groundwater quality;;
- Improved definition of groundwater flow directions in the area of the mine site;
- Additional assessment of the lateral continuity of identified hydrostratigraphic units, associated potential aquitards and the potential for downward migration of groundwater and COCs;
- Evaluation of any current contribution of constituents of potential concern by surface mine units;
- Evaluation of the effectiveness of the existing pumpback system in limiting mine-related groundwater from leaving the northern margin of the mine site;
- Evaluation of recharge and discharge components to the alluvial groundwater flow system beneath the mine site; and
- Establishment of Closure Plan options to address any human health and ecological risk associated with the potential groundwater pathway.

3.1 Proposed Site Investigations

Site investigations anticipated under this Work Plan consist of the following activities:

- Drilling of additional monitor wells and piezometers in strategic locations and depths to provide information to address the issues, and answer the questions, listed above;
- Confirmation of coordinates and elevations of existing wells, and surveying of new monitor wells and other related features;
- Measurements of groundwater elevations on a quarterly basis for one year in existing and proposed monitor wells to define seasonal variations in groundwater flow;
- Collection and analyses of groundwater quality samples in existing and proposed monitor wells for one year to assess seasonal variations in groundwater quality,

- Collection of information on the quality and quantity of groundwater applied to the agricultural area located northeast of the mine site;
- Installation of moisture monitoring probes in representative surface mine units such as tailings and waste rock materials to collect information on potential wetting front migration from unsaturated portions of these mine units to evaluate the potential for future leaching of constituents of concern to shallow alluvial groundwater;
- Observations of surface water in the Wabuska Drain, West Campbell Ditch and Walker River channel at selected locations on a quarterly basis in conjunction with groundwater monitoring to improve the evaluation of groundwater gradients and flow directions.

Previously, Atlantic Richfield submitted two draft Work Plans: *Draft Work Plan for Yerington Mine Site: Groundwater Pumpback System Trench Testing* and *Draft Work Plan for Yerington Mine Site: Hydropunch Evaluation*. These Work Plans were submitted prior to the approval of the Scope of Work, which anticipated their inclusion in this Groundwater Conditions Work Plan. Based on the information presented in Sections 1.3 and 2.0, Atlantic Richfield proposes not to include these activities in this Work Plan for the following reasons:

Trench testing was proposed to evaluate the hydrostratigraphy of the shallow alluvial aquifer in the area north of the mine site, and to visually demonstrate which stratigraphic zones transmit groundwater in the area of the pumpback well system, and to assess the viability of using cut-off trenches to limit the off-site migration of mine-related groundwater. Recent core drilling to install monitor well MW2002-1 indicated no obvious hydrostratigraphic horizons, and the preliminary observations of material characteristics of the recovered core suggested that trenching without backfilling could result in a geotechnically unstable trench. Therefore, until further groundwater and aquifer information is obtained through the implementation of this Work Plan, the concept of trench testing is not further proposed.

Hydropunch evaluations were proposed to select monitor well installation locations in the area north and northwest of the mine site. Given the recent completion of monitor wells MW-2002-1 and –2 in June 2002 in these areas, the hydropunch evaluation is no longer necessary. Locations for monitor well installations proposed in this Work Plan will be based on the available data and hypothesis testing related to the site conceptual hydrogeologic model.

Monitor Well and Piezometer Drilling

The locations of proposed monitor wells and piezometers (for groundwater elevation observations) to be constructed under this Work Plan are shown in Figure 19. Table 6 presents the technical rationale for each monitor well, well cluster, or piezometer. All well boreholes will be drilled using a drilling technique that allows for an evaluation of hydrostratigraphy at the mine site (i.e., collection of lithologic samples suitable for logging). All monitor wells and piezometers will be constructed to allow for the collection of groundwater elevation measurements and, for monitor wells, the collection of water quality samples. For shallow completions, nominal five-foot screen intervals will be constructed in the upper 10 feet of saturated alluvium beginning at least 5 feet below the water table. Deeper completions in the alluvial aquifer will be constructed on the basis of stratigraphic information (e.g., below apparent clay-rich zones), with exact screen depths to be determined in the field. The Data Summary Report for Groundwater Conditions will present all pertinent information from the well drilling and construction activities.

Well Surveying

All existing wells shown in Figure 8B will be re-surveyed in conjunction with the surveying of new monitor wells and piezometers installed under this Work Plan. Survey results will be reported to the nearest 0.01-foot, and summarized in the Data Summary Report. Locations to be selected along the West Campbell Ditch and Walker River will be surveyed to establish gradient control for groundwater elevations.

Moisture Monitoring

Moisture measurements will be obtained quarterly for depth-specific intervals in boreholes constructed within the Sulfide Tailings Area, Oxide Tailings Area and South Waste Rock Area, as shown in Figure 19 and described in Table 6. These measurements will be made to evaluate the potential for meteoric water to migrate through the unsaturated surface mine units, represented by the three locations shown in Figure 19. Three depth-specific moisture monitoring probes will be installed at each location in conjunction with laboratory moisture measurements for solid samples collected during drilling. The precise depth of each installed moisture probe will be determined at the time of drilling.

Groundwater Elevation Measurements

Groundwater elevation measurements from existing and new wells, and from piezometers, will be taken on a quarterly basis for one year. All measurements will be recorded to the nearest 0.1-foot. Hydrographs will be developed and presented in the Data Summary Report.

Surface Water Observations

Observations of surface water flows will be made at the locations shown in Figure 19 in conjunction with groundwater elevation measurements. Observations in the Walker River channel and West Campbell Ditch will provide gradient control for groundwater elevation contour mapping (on the basis that surface water flows will recharge groundwater along the length of these features). Observations of flowing water in the Wabuska Drain at the location shown in Figure 19 will indicate the relative elevation of groundwater at that location.

Groundwater Quality Sampling and Analyses

Groundwater quality samples and analyses from existing and new monitor wells will be obtained on a quarterly basis for one year. Domestic wells will be sampled once during the one-year monitoring period. Sampling techniques are described in Section 3.2 and analytical parameters and associated information are provided in Table 7. Analytical results and time-concentration plots will be presented in the Data Summary Report.

Collection of Irrigation Water Information

Available information regarding the quality and quantity of water applied to the agricultural area north of the mine site will be collected and compiled in the Data Summary Report. To the extent possible, this information will be integrated with groundwater elevation and water quality data from monitor wells located within, or adjacent to, the agricultural area to assist in understanding site groundwater conditions.

3.2 Quality Assurance/Quality Control Procedures

Proposed site investigation activities will follow the quality assurance/quality control (QA/QC) procedures described in this section to ensure that the type, quantity and quality of data collected are reliable and provide the information needed to satisfy the DQOs listed in Section 1.4. QA/QC issues include:

- Monitor well and piezometer drilling, construction and surveying;
- Installation of moisture monitoring probes;
- Collection of field data and sampling protocols, including handling and shipment;
- Selection of appropriate analytical laboratory detection limits; and
- Identification of confidence levels for the collected data.

Monitor Well and Piezometer Drilling and Construction

All monitor well and piezometer boreholes will be drilled using a drilling technique that allows for lithologic logging of borehole samples to assist in the evaluation of site hydrostratigraphy. All wells will be constructed to allow for the collection of groundwater elevation measurements and, for the monitor wells, water quality samples. The Data Summary Report for Groundwater Conditions will present all pertinent information from the well drilling and construction activities.

The monitor wells will be constructed of two-inch diameter, Schedule 40 PVC flush-coupled well casing and nominal 0.02-inch slotted screens. The piezometers will be constructed of one-inch diameter, Schedule 40 PVC flush-coupled well casing and nominal 0.02-inch slotted screens. Five-foot screened intervals will be installed in the upper 10 feet of saturated alluvium with a filter pack consisting of nominal 10/20 silica sand. Deeper completions in the alluvial aquifer will be constructed below apparent clay-rich zones, with screen depths to be determined in the field. The remaining annulus will be backfilled with bentonite or grout to the natural ground surface. The wells will be completed with a nominal two-foot casing above the ground surface, cemented in-place, and locking caps installed at the top of the well casings.

Monitor Well and Piezometer Surveying

Measurement of latitude/longitude coordinates and top-of-casing elevations for existing and new monitor wells will be conducted with a real-time kinematic global-positioning satellite (GPS) device. This portable device allows an accuracy of at least three millimeters (0.01 feet) for latitude, longitude, and elevation. This degree of accuracy is sufficient for water level measurements to be used in the calculation of groundwater direction and hydraulic gradient. Measurements of coordinates and elevations will be recorded in the field notebook immediately after readings are observed, and will be automatically logged in the GPS data-logger for later down-loading and cross-checking of data recorded in the field. The coordinates will be used to properly position the wells on a site plan, along with a permanent record of each well top-of-casing elevation. For the purpose of field measurement, the top of the well casing will be the highest point on the rim of the casing.

Groundwater Field Parameters

Field measurements will include static groundwater elevations, dissolved oxygen, pH, electrical conductivity and temperature. The field parameter measurements will be recorded to the accuracy allowed by the measurement method and equipment, with particular attention being given to proper calibration of instruments. Prior to sampling at each monitoring well, the pH, dissolved oxygen, temperature, and electrical conductivity probe(s) will be calibrated and the conductivity probe will be checked with a standard. Proper operation of the ground water elevation probe will be checked prior to use by immersing the probe in water to ensure the audible signal is produced. After sampling is completed, a drift check will be performed with each instrument, using the same standard solutions used to calibrate. The purpose of the drift check is to assess the loss of accuracy that often occurs when measurements are performed at different locations. Instrument calibration information and instrument accuracy limits will be recorded in the field notebook and presented in the Data Summary Report. The methods and minimum detection limits of the pH, dissolved oxygen, temperature, and electrical conductivity devices are shown below:

GROUNDWATER FIELD PARAMETERS		
Parameter	**Method**	**Detection Limit**
Conductivity	EPA 120.1, meter	1.0 µS/cm
Dissolved Oxygen	EPA 360.1, probe	0.1 mg/l
PH	EPA 150.1, meter	0.1 standard units
Temperature	Standard Methods 212, Thermometer	0.1 ^{o}C

To the extent practicable, field parameters will be measured in one day to limit error in calculating hydraulic gradient or flow direction due to potential diurnal fluctuations in groundwater elevation. All measurements will be recorded in a bound field notebook. All equipment used to measure depth-to-water and other physical parameters in each well will be decontaminated between wells by washing in an Alconox detergent solution with subsequent clean-water rinse.

Groundwater Sampling

New and existing monitor wells will be purged using either a submersible pump or clean, disposable Teflon bailer, depending on depth-to-water, total depth of the well, and well diameter. The equipment and purging method used for monitor wells will be noted on each field data sheet. During purging, pH and electric conductivity will be monitored with a calibrated, portable field instrument in order to determine stabilization of these parameters between each purged well casing volume. As appropriate (e.g., for monitor wells or pumpback wells), a minimum of three casing volumes will be purged from each well until pH and electric conductivity readings stabilize to within 10 percent of the previous casing volume. If a well is purged dry, no sample will be collected until it has recharged to within 80 percent of its original depth-to-water, or no more than 24 hours. Larger capacity wells (e.g., production or domestic wells) will be sampled after field parameters have stabilized.

After field parameters have stabilized, a groundwater sample will be collected using a disposable Teflon bailer, discharge from the submersible pump or, for domestic wells, from the tap. The sample will be decanted into an appropriate sample container depending on the required analysis. Both filtered samples for dissolved metals and, for selected monitor wells and domestic wells, unfiltered samples for total metals will be each collected in 500-milliliter (mL) bottles. Samples for dissolved metals analysis will be filtered through a 0.45-micron filter. Immediately after collecting the water sample for total metals, and filtering for dissolved metals, nitric acid will be added to each dissolved or total metals sample container until the pH of the sample is less than 2. Non-metals samples will be collected in 1,000-mL bottles, unfiltered, with no acid preservation. Sample bottles for the blank will not be triple-rinsed prior to being filled, so that any contamination from bottles alone would be detected. Immediately following collection, samples will be placed into an insulated cooler chilled with ice to an approximate temperature of four degrees centigrade. The samples will then be transported to the analytical laboratory via overnight mail or personal delivery. Sample containers, preservation methods, and filtering methods are summarized below.

Decontamination of purging equipment will be performed between each well by submerging and scrubbing the outside of the pump and associated hosing in an Alconox detergent bath, then twice rinsing the outside of the pump in deionized water. At least five gallons of Alconox detergent solution and then five gallons of deionized water will be run through the internal portion of the pump to reduce the potential of cross contamination between wells.

Sample Identification and Preservation

Sample labels will be completed and attached to each laboratory sample container prior to ground water collection. Strict attention will be given to ensure that each sample label corresponds to the collection sequence number marked on the bottle prior to sample collection. The labels will be filled out with a permanent marker and will include the following information:

- Sample identification (well location)
- Sample date
- Sample time
- Sample preparation and preservative
- Analyses to be performed
- Sample type
- Person who collected sample

Each sample will be tracked according to a unique sample field identification number assigned when the sample will be collected. This field identification number consists of three parts:

- Sampling event sequence number
- Sampling location
- Collection sequence number

For example, the sample collected during the third sampling event at monitoring well MW-4 will be labeled: 003MW004. Blanks and duplicate samples for quality assurance will be labeled in the same fashion, with no obvious indication of their sample location or quality. For example, the duplicate sample to the one stated above might be labeled: 003MWD111, with a field notebook note that this identification number corresponds to 003MW004. Procedures for maximum holding times, storage conditions, and preservative method are presented below:

SAMPLE CONTROL PROCEDURES						
Parameter	**Amount for Analysis**	**Container**	**Filtering**	**Maximum Hold Time**	**Storage Conditions**	**Preservatives**
TDS, TS	1,000 mL	1,000 mL HDPE	None	7 days	4°C	none
Sulfate, Chloride, Bromide, Flouride	500 mL	1,000 mL HDPE	None	28 days	4°C	none
Nitrate	100 mL	1,000 mL HDPE	None	48 hours	4°C	H_2SO_4 to pH<2
Total Metal	Varies per metal	500 mL HDPE	None	6 months*	4°C	HNO_3 to pH<2
Dissolved Metal	Varies per metal	500 mL HDPE	0.45 µm	6 months*	4°C	HNO_3 to pH<2
Acidity/ Alkalinity	100/200 mL	500 mL HDPE	None	14 days	4°C	none

TDS= Total Dissolved Solids
TS= Total Solids
HNO_3= Nitric acid

* Mercury= 28 days; Chromium VI= 24 days
HDPE= High-density polyethylene
H_sSO_f= Sulfuric Acid

The following sample preservation methods will be followed for collected groundwater samples:

- If the sample is to be analyzed for dissolved metals, filter sample through a 0.45-micron filter using an inline filter immediately after sample collection. After filtering, add nitric acid to the sample until the pH is less than 2.
- If the sample is to be analyzed for total metals, do not filter. Add nitric acid to the collected sample until the pH is less than 2.
- Check the pH by pouring a small amount of sample into the bottle cap and checking the pH with pH paper.
- Discard the liquid in the cap after checking the pH.
- Replace the cap, place the sample container in a sealed zip-loc plastic bag, and cool the sample to 4°C by immediately placing it in an insulated chest with containerized ice.
- Indicate on the sample label what the requested analysis is (e.g., dissolved or total).

- Observe the maximum holding times and storage conditions for all collected water samples.

Sample Handling and Transport

The QA objectives for the sample-handling portion of the field activities are to verify that decontamination, packaging and shipping are not introducing variables into the sampling chain which could render the validity of the samples questionable. In order to fulfill these QA objectives, blank and duplicate QC samples will be used as described below. If the analysis of any QC samples indicates that variables are introduced into the sampling chain, then the samples shipped with the questionable QC sample will be evaluated for the possibility of contamination.

Duplicate samples will be collected at a frequency of one in eight-to-ten samples for each analysis. Duplicate samples will be collected by filling the bottles for each analysis at the same time the original sample is collected. Each sample from a duplicate set will have a unique sample number labeled in accordance with the identification protocol, and the duplicates will be sent “blind” to the lab (i.e., no special labeling of the duplicate will be provided).

A field sample will be designated as the “lab QC sample” at a frequency of 1 per 20 samples (including blanks and duplicates) for all parameters. The lab QC sample is the sample the laboratory will use for its internal quality control analyses. The lab QC sample for water analyses will be a double volume sample. The lab QC sample will be a sample that is representative of other contaminated samples. The sample containers and paperwork will be clearly labeled “Lab QC Sample”.

A blank sample will be collected by pouring the blank water directly into the sample bottles at one of the sample locations. De-ionized water will be used for collecting blank water samples. Field blanks will be labeled in the same manner as other samples and will be sent “blind” to the lab, with no special indication of the nature of the sample.

Chain-of-custody protocol will be followed throughout the transport process. Each chain-of-custody will contain the following information:

- Project name
- Sampler's name and signature
- Sample identification
- Date and time of sample collection
- Sample matrix
- Number and volume of sample containers
- Analyses requested
- Filtration completed or required
- Method of shipment

The following sample packaging and shipment procedures will be followed for collected water samples to ensure that samples are intact when they arrive at the designated laboratory:

1. Place a custody seal over each container, and place each container in a zip-loc plastic bag and seal the plastic bag shut.
2. Place the sealed containers in the insulated ice chest.
3. If required, fill empty spaces in the ice chest with either ice, pelaspan (styrofoam popcorn), or bubble-pack wrap to minimize movement of the samples during shipment. Contained ice will be double bagged in zip-loc plastic bags to avoid water leakage.
4. Enclose the chain of custody form and other sample paperwork in a zip-loc plastic bag. If shipping the ice chest, tape the plastic bag to the inside of the ice chest lid. If self-transporting the ice chest, tape the plastic bag to the outside of the ice chest lid. Keep a copy of all paperwork.
5. Seal the ice chest shut with strapping tape and place two custody seals on the front of the cooler so that the custody seals extend from the lid to the main body of the ice chest. Place clear tape over each custody seal on the outside of the ice chest.
6. If shipping the ice chest, label it with "Fragile" and "This End Up" labels. Include a label on each cooler with the laboratory address and the return address.
7. Transport ice chests to the appropriate laboratory within 24 hours by hand-delivery or via express overnight delivery.

<u>Laboratory Analyses and QA/QC</u>

Laboratory analyses for groundwater samples collected as part of this Work Plan will be conducted in accordance with Table 7. Groundwater samples will be analyzed for dissolved and/or total metals, sulfate, nitrate, chloride, acidity, alkalinity, hardness and total dissolved solids. A Nevada-certified laboratory will perform laboratory analyses. Criteria that are qualitative and quantitative indictors of laboratory data quality are precision, accuracy, representiveness, completeness and comparability, as described below:

- Precision is a measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions (usually expressed in terms of the relative percent difference or standard deviation).
- Accuracy is the degree of agreement of a measurement with an accepted reference or true value. Usually expressed in terms of percent recovery.
- Representiveness refers to a sample or group of samples that reflects the characteristics of the media at the sampling point. It also includes how well the sampling point represents the actual parameter variations.
- Completeness describes the amount of valid data obtained from a series of measurements relative to the amount that anticipated to achieve the DQOs for this Work Plan.
- Comparability expresses the confidence with which one data set can be compared to another. Data comparability can be ensured by reporting each data type in consistent units (e.g., all field measurements will be reported in consistent units and analytical methods will be similar or equivalent for all rounds of sampling). Comparability and representiveness are also ensured by the use of established field and laboratory procedures and their consistent application.

Documentation

Summary of field measurement and sampling activities will be recorded in a field notebook with integral bound pages, and entries will contain accurate and inclusive documentation of project activities in objective and factual language. Entries will be made using permanent waterproof ink, and erasures are not permitted. Errors will be single-lined out, should not be obscured, and initialed and dated. The person making the entries will sign at the beginning and the end of the day's entries, and a new page will be started for each day.

The following entries will be made to the bound site logbook and/or filed log sheets:

- General descriptions of weather conditions
- Location of each sampling point
- Data and time of sample collection (field log sheets.)

- The type of blank collected and the method of collection
- Field measurements made, including the date and time of measurements
- Calibration of field instruments
- Reference to photographs taken
- Date and time of equipment decontamination
- Field observations and descriptions of problems encountered
- Duplicate sample location

Moisture Monitoring

Changes in moisture content of representative surface mine units will be evaluated using volumetric water content measurements with electronic in-situ sensors (probes), which indicate the quantity of moisture present in a given volume of soil. The sensors, in direct contact with the mine unit materials, measure the electrical capacitance in an internal circuit when a small voltage is applied from a hand-held meter or data logger. The magnitude of capacitance is affected by the amount of soil moisture along the outer surface of the sensor. The instrument correlates the electrical capacitance measurements to moisture content. Initial soil moisture calibrations will be made with laboratory measurements from samples, collected at the time of drilling and sensor installation, corresponding to the depth of the installed probe.

Boreholes will be drilled to allow for probe placement in close proximity to the surface mine materials (the diameter of a soil moisture sensor is approximately 1.5 inches). Borehole cuttings or core will be used to backfill the borehole between each sensor. The following procedure will be followed during the installation of the soil moisture sensors (NOAA, 2002:

1. Soak each sensor in clean water for 1 to 2 hours to remove the air and then allow drying for 4 to 6 hours. Soak at least five minutes prior to placing the sensor in the borehole.
2. Mix drilled materials with enough distilled water to form four gallons of thick, semi-fluid mud with no visible air gaps to achieve adequate sensor contact with the materials.
3. Pour one gallon of the mixture into the bore hole, and lower the sensor to the desired depth (where the bottom of the sensor touches the mixture).
4. Fill the hole around the sensor by adding the remaining three gallons of mixture, followed by the drilled materials and a little water at a time to enhance compaction, until the hole is filled to the depth of the next sensor level.

5. Allow at least one week for equilibration of the mud with surrounding native soil before recording the first "true" soil moisture measurements. To ensure equilibration, record the change in soil moisture every 12 hours, and graph results until the curve becomes relatively asymptotic.
6. Mark each sensor lead with a permanent tag indicating the exact depth of the sensor. Allow a minimum of six feet of lead to protrude from the ground surface.
7. Install an eight-inch diameter steel casing around the wire leads. The casing should extend from a minimum of one-foot bgs to two-feet above ground surface, and be open at the top, with no cap.

3.3 Site Job Safety Analysis

A site-specific Job Safety Analysis (JSA) is presented in Appendix D. This JSA has been prepared in the context of the Health and Safety Plan (SHSP) for the Yerington Mine Site. The SHSP identifies, evaluates and prescribes control measures for health and safety hazards, and describes emergency response procedures for the site. SHSP implementation and compliance will be the responsibility of Atlantic Richfield's contractor, with Atlantic Richfield taking an oversight and compliance assurance role. Any changes or updates will be the responsibility of the contractor with review by Atlantic Richfield Safety Representative Lorri Birkenbuel. Copies of the SHSP are located at the site, in Atlantic Richfield's Anaconda office, and in the contractor's office. The SHSP includes:

- Safety and health risk or hazard analysis;
- Employee training records;
- Personal protective equipment (PPE);
- Medical surveillance;
- Site control measures (including dust control);
- Decontamination procedures;
- Emergency response; and
- Spill containment program.

The SHSP includes a section for site characterization and analysis that will identify specific site hazards and aid in determining appropriate control procedures. Required information for site characterization and analysis includes:

- Description of the response activity or job tasks to be performed;
- Duration of the planned employee activity;
- Site topography and accessibility by air and roads;
- Safety and health hazards;
- Hazardous substance dispersion pathways; and
- Emergency response capabilities.

All contractors will receive applicable training, as outlined in 29CFR 1910.120(e) and as stated in the SHSP. Copies of Training Certificates for all site personnel will be attached to the SHSP. Personnel will initially review the JSA forms at a pre-entry briefing. Site-specific training will be covered at the briefing, with an initial site tour and review of site conditions and hazards. Records of pre-entry briefings will be attached to the SHSP.

Elements to be covered in site-specific training include: persons responsible for site-safety, site-specific safety and health hazards, use of PPE, work practices, engineering controls, major tasks, decontamination procedures and emergency response. Other required training, depending on the particular activity or level or involvement, may include MSHA or OSHA 40-hour training and annual 8-hour refresher courses. Other training may include, but is not limited to, competent personnel training for excavations and confined space. Copies of site personnel MSHA or OSHA certificates will be attached to the SHSP.

The JSA for this Work Plan incorporates individual tasks, the potential hazards or concerns associated with each task, and the proper clothing, equipment, and work approach for each task. Tasks and associated potential hazards included in the JSA are outlined below:

PROJECT TASKS AND ASSOCIATED POTENTIAL HAZARDS YERINGTON MINE SITE	
SEQUENCE OF BASIC JOB STEPS	**POTENTIAL HAZARDS**
1. Well/Piezometer/Moisture Probe Installation: drilling rig mobilization and setup	1. Traffic and pedestrian mishaps and resulting bodily injury. 2. Drilling into underground utilities 3. Striking overhead lines or objects with drill mast. 4. Physical hazards associated with handling and transferring fuel to machinery. These include ignition/explosion, dermal irritation, inhalation of fumes, accidental ingestion, and eye contact.
2. Well/Piezometer/Moisture Probe Installation: drilling activities	1. Injury to hearing from noise. 2. Inhalation hazards from dust from drilling activities. 3. Physical injury from moving parts of machinery. 4. Physical hazards to personnel on the ground in the vicinity of the heavy machinery.
3. Well/Piezometer/Moisture Probe Installation: construction	1. Inhalation of silica sand, bentonite, or concrete dust. 2. Eye injury or irritation from splashing ground water. 3. Physical hazards associated with use of hand tools to tighten or loosen augers.
4. Surveying	1. Traffic and pedestrian mishaps and resulting bodily injury. 2. Lightning.
5. Collect Monitoring Well Field Parameter Measurements	1. Skin irritation from dermal or eye contact. 2. Slipping or falling on wet ground surface.
6. Purge Monitoring Wells	1. Skin irritation from dermal or eye contact. 2. Slipping or falling on wet ground surface.
7. Prepare sample bottles and dress in appropriate PPE.	1. Burn or corrosion from acid spillage, if sample bottles do not have acid already in them.
8. Collect Ground Water Samples and Decontaminate Equipment	1. Skin irritation from dermal or eye contact. 2. Slipping or falling on wet ground surface.
9. Package and Transport Groundwater Samples to Laboratory	1. Traffic and pedestrian mishaps and resulting bodily injury.
10. All Activities	1. Slips, Trips, and Falls
	1. Back, hand, or foot injuries during manual handling of materials.
	1. Heat exhaustion or stroke.
	1. Hypothermia or frostbite.
Unsafe conditions.	1. All potential hazards.

SECTION 4.0

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FIGURES